

Theoretical substantiation of a type of wheel farm tractors for Ukraine

V. Adamchuk,

Academician of NAAS Doctor of Engineering,

National Science Center "Institute of Mechanization and Electrification Agriculture"

V. Bulgakov,

Academician of NAAS Doctor of Engineering,

National University of Bioresources and nature use of Ukraine

V. Nadykto,

Corresponding Member of NAAS, Doctor of Engineering

V. Kiurchev,

Corresponding Member of NAAS, Doctor of Engineering *Tauria state agrotechnological university*

The purpose. To develop new theoretical bases of definition of a type and to determine the range of change of nominal traction effort of wheel farm tractors. **Methods.** Substantive provisions of the theory of tractor, higher mathematics, in particular laws of geometrical progression and the theory of numbers are used. **Results.** On the basis of the advanced theoretical approaches the type of wheel farm tractors is developed for the first time for Ukraine. For each traction class the technique of determination of average value and possible (admissible) range of change of nominal traction effort is offered. **Conclusions.** New type of wheel farm tractors for Ukraine should be presented by power means of 5 basic traction classes: 0,6; 1,1; 1,8; 3 and 5. Each of the resulted figures means the nominal traction effort of a tractor reduced exactly in 10 times ($P_{tr.n}$) which is measured in kN. The range of change of this parameter for each power means of this or that traction class should be within the definite limits.

Key words: tractor, type, power means, nominal traction effort, operational mass, speed of movement.

Formulation of the problem

The main mobile power tool in the agricultural production of any country was and in the near future will remain a tractor. Therefore, Ukraine, where agriculture is seen as the locomotive of the entire economy, must necessarily have a clear tractor policy, the organizational basis of which should be the type of mobile energy.

This unique guideline is highly needed for the following reasons. Its presence will harmonize the activities of tractor and farm machine builders. After all, the first at the level of the relevant rules will be asked in advance, due in due course the range of changes in the basic design parameters of energy resources, which when designing machines / tools will be required to take into account the second. The result of such coherence of their constructive actions will be the creation of a Machinery system, in the absence of which, in principle, not bad energy (tractor) and technological (machines / tools) parts of the machine-tractor unit (MTA) may not be adapted to each other with all the resulting disadvantages.

Today Ukraine, although positioning itself as a country with a powerful agricultural sector, does not have its own tractor type. Let it be formally, but scientists, designers and production operators continue to use the old GOST 27021-86 and / or ST SEV 628-85 in modern conditions, a typical range of agricultural tractors which includes 10 traction classes. As can be seen from Table 1, by its very nature, it is a growing sequence of dimensionless numbers from 0.2 to 8. Each of them expresses a significant nominal tractor traction effort ($P_{кр.н}$) in tons, since the formation of this type originated during the action of the old system of measuring physical quantities.

1. Tractor type according to GOST 27021-86 (ST SEV 628-85)

№	Traction class	Nominal traction effort, $P_{кр.н}$ (kN)	№	Traction class	Nominal traction effort, $P_{кр.н}$ (kN)
1	0.2	від 1.8 до 5.4	6	3	від 27 до 36
2	0.6	від 5.4 до 8.1	7	4	від 36 до 45
3	0.9	від 8.1 до 12.6	8	5	від 45 до 54
4	1.4	від 12.6 до 18	9	6	від 54 до 72
5	2	від 18 до 27	10	8	від 72 до 108

According to the plan, the values $P_{кр.н}$ (in kN) should represent a geometric progression whose denominator (q) would be determined from the subsequent dependence [1]:

$$q = n - 1 \sqrt[n-1]{\frac{P_{кр\ max}}{P_{кр\ min}}}, \quad (1)$$

where $P_{кр\ max}$, $P_{кр\ min}$ – the upper and lower values of the entire range of traction efforts of tractors; n - the number of members of a series (traction classes).

It was assumed that, for a rationally-shaped, standard range, the intervals between the traction ranges of adjacent classes of tractors should be absent, the ranges themselves were the same, and the q -ratio denominator equal to the ratio of the maximum (P_{max}) and the minimum (P_{min}) tractive effort of the same traction range. That is

$$q = P_{max} / P_{min} \quad (2)$$

We emphasize that during the whole period of practical application of this type of tractors, it was not effective for the conditions of Ukraine, and therefore was subjected to constant and thorough criticism on the part of its scientists [2, 3]. Moreover, not only with regard to the required number of traction classes, but also methods for determining the range of changes in the nominal traction energy of an energy source.

The aim of the study. Presentation of a new variant of the type of agricultural wheeled tractors. At the same time, the authors do not put the problem to be necessarily better than the current, since there is (and can not exist) a single algorithm for its development. More importantly, in order to be in a certain way methodically substantiated and its practical realization was possible on the material and technical base of our country.

Research methods. First, we agree on the type of tractors to call a typical size of agricultural mobile power means of a certain number of traction classes in the form of a growing sequence of dimensionless numbers, each of which expresses a reduced ten times the nominal tractor traction effort ($P_{кр.н}$). It is him (traction effort), and not the installed engine power, we take for the classification parameter of the above-mentioned standard-size series. The advantages of this approach are quite convincing, in our opinion, set out in scientific papers [4-6].

Secondly, the dependence (1) and (2) will be considered as the main theoretical postulates necessary for the development of a new type of tractor. Equating their right parts, after transformations we obtain an expression for calculating the number of traction classes of tractors (n):

$$n = Integer \left[1 + \frac{\lg \left(\frac{P_{кр\ max}}{P_{кр\ min}} \right)}{\lg \left(\frac{P_{max}}{P_{min}} \right)} \right]. \quad (3)$$

Research results. Unknown values of $P_{кр\ max}$ and $P_{кр\ min}$ expression (3) we will find for the following considerations. The most energy-intensive traction gun is, as you know, the plow. Its traction resistance ($P_{кр}$) is calculated from the expression :

$$P_{kp} = n_k \cdot b_k \cdot h \cdot K_o, (4)$$

црyкy n_k – number of plow shells; b_k – width of capture of one body of aeration instrument, m; h – plowing depth, m; K_o – coefficient of specific traction resistance of the plow, kN / m².

The width of the capture of one housing of the plow is assumed to be equal to $b_k = 0.40$ m. This, as practice shows, allows better degradation of the arable layer of soil and apply in the furrow widespread tires of a standard size of 16.9R38, whose profile width is 0.43 m. Tires of this The same standard size in a furrow formed by a plow case with a width of capture of 0,35 m or less, for some reason, is rather problematic..

For V.R. Williams [7] maximal depth of plowing with obligatory use of pre-bowl (without it this technological operation from the point of view of preservation of the structure of the soil is impossible) should not exceed $h = 0,30$ m.

And the last. In southern Ukraine, under normal conditions of plowing, the specific traction resistance of plows, as evidenced by many years of research authors, usually does not exceed 55 kN / m². On a dried ground (humidity less than 10%), the K_o index can reach 60 ... 66 kN / m², but plowing under such conditions is too energy intensive, and therefore rather unwanted than possible.

Accepting the lowest significant overall operating range of traction efforts of tractors $P_{kp\min} = P_{kp}$, taking into account the foregoing, we have:

$$P_{kp\min} = 1 \cdot 0,4 \cdot 0,30 \cdot 55 = 6,6 \text{ кН.}$$

Practice shows that if the width of the capture of one plow body is 0.40 m, the maximum number of them should not exceed 8. Otherwise, the construction of the aeration instrument, due to its considerable length, may not adequately copy the longitudinal profile of the cultivated field. Foreign experience shows that the plow frame should be hinged. And this in a way not only complicates its design, but also leads to a significant rise in price.

Hence it turns out that

$$P_{kp\max} = 8 \cdot 0,4 \cdot 0,30 \cdot 55 = 52,8 \text{ кН.}$$

In the expression (3) the maxima remain unknown (P_{\max}) and minimal (P_{\min}) The traction effort of a tractor of a pulling class is important. In practice, these values are convenient to represent them with coefficients of use of the coupling weight of–dimensionless analogues the energy product, that is $\varphi_{kp\max}$ and $\varphi_{kp\min}$ in accordance.

The first of these coefficients is limited to the maximum allowable ($\delta_{\text{дон}}$) by pushing the tractor's engines (in this case, the wheel). As highlighted in [8], in order to maintain the structure of the soil value $\delta_{\text{дон}}$ in the spring-summer period of field work should not exceed 9, 12 i 15% for tractors of traction classes (according to the old classification) 1,4; 3 i 5 in accordance. Under of the propulsion these conditions, the dependence (δ) of the hitching of the power tool on the traction effort developed by it, expressed through the widely known dimensionless coefficient of use of the coupling weight of the tractor (φ_{kp}), is linear:

$$\delta = a \cdot \varphi_{kp} + b,$$

where a and b constants of approximation.

Taking into account this the dependence of the traction efficiency of the tractor (η_{τ}) from the coefficient φ_{kp} is such 9 :

$$\eta_m = \frac{\eta_{mp} \varphi_{kp} (1 - a \cdot \varphi_{kp} - b)}{\varphi_{kp} + f}, (5)$$

where f coefficient of resistance to rolling energy.

The averaged graphical interpretation of the laws (5) for wheeled tractors for their functioning on agrotechnical backgrounds, the "field prepared for sowing" and "stern" with the pushing of engines is not more than 15%, is represented by curve 1 (Fig.). From its analysis, we see that the linear nature of the dependence $\delta = f(\varphi_{kp})$ traction efficiency of the tractor has no optimum. Its maximum value reaches the mark 0,62 at $\varphi_{kp\max} = 0,4$.

The minimum value of the tractive effort of the tractor P_{\min} coefficient of use of coupling weight of a tractor – or its dimensionless analogue ($\varphi_{\text{крmin}}$) – will be limited by the speed factor μ , which is determined from the expression 1 :

$$\mu = V_i / V_o,$$

where V_i – the speed of the tractor for one or another significance of the coefficient $\varphi_{\text{кр}}$; V_o tractor speed at $\varphi_{\text{крmax}}$.

It should be emphasized that in the range $\varphi_{\text{кр}}$ to 0 до $\varphi_{\text{крmax}}$ value $V_i \geq V_o$. With this in mind when $\varphi_{\text{кр}} = \varphi_{\text{крmax}}$ coefficient of speed μ is minimal and equal to 1.

We will determine its maximum level for the following reasons. The analysis of the technical characteristics of most modern agricultural machines / tools indicates that their range of operating speed varies from approximately $V_{\min} = 7$ to $V_{\max} = 16$ km/h. The ratio of these quantities (i.e. $V_{\max}:V_{\min}$), which is 2.2, we will accept for the maximum significant coefficient of speed μ .

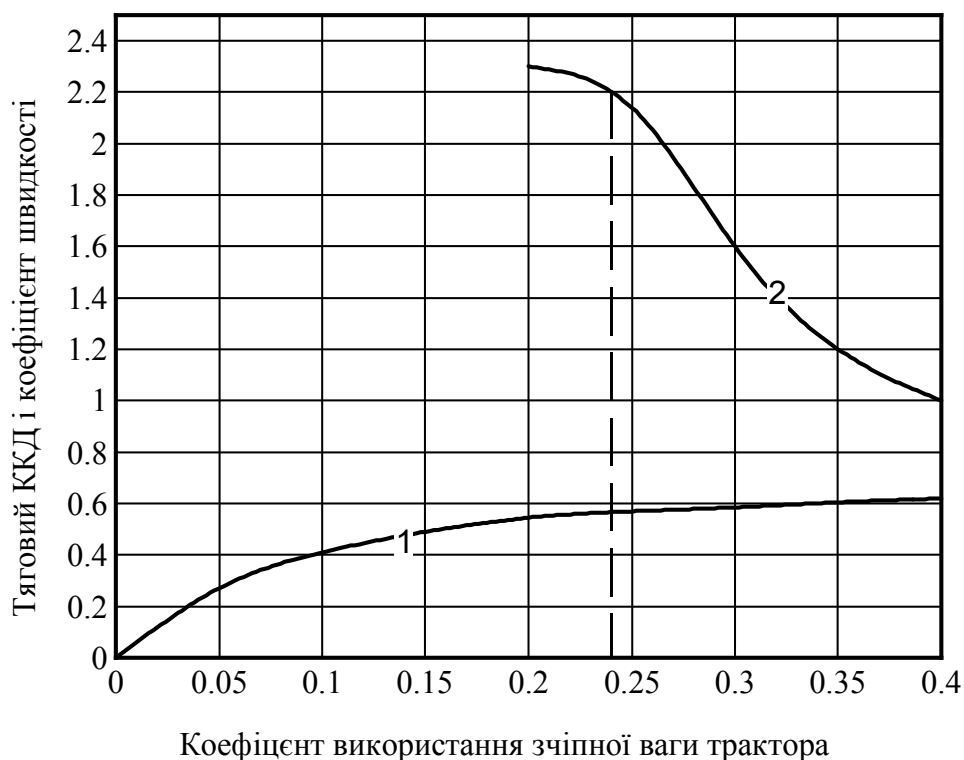


Fig.1. Dependence of the coefficient of speed (2) and traction efficiency of the tractor (1) from the coefficient of using its coupling weight

The average dependence of the traction efficiency of wheeled tractors on the change of this coefficient is represented by curve 2 (see Fig.). As the analysis shows, with $\mu = 2,2$ the minimum value of the coefficient of use of the coupling weight of the wheeled tractor $\varphi_{\text{крmin}} = 0,24$.

It is clear that the essence of the relationship $\varphi_{\text{крmax}}/\varphi_{\text{крmin}}$ is nothing like a relationship $P_{\text{max}}/P_{\text{min}}$ and, at the same time, - the above-mentioned denominator of a standard-size series of tractors type q. In this case

$$\varphi_{\text{крmax}} / \varphi_{\text{крmin}} = P_{\text{max}} / P_{\text{min}} = q = 0,4 / 0,24 = 1,67. \quad (6)$$

Taking into account (6), and also above the established values $P_{\text{крmin}}$ and $P_{\text{крmax}}$, From expression (3) we find that a typical size series of tractors must include five members (that is, $n = 5$). The denominator of this series (q) is rounded to a value of 1.7. It is this number by the classification of the French engineer Charles Renard is among the prevalent among a number of its five values.

Taking into account the above definition of the type of tractors, the algorithm for its calculation is as follows:

$P_{kp\ max} = 52,8$ kN – this is a class 5; nominal tractor traction effort – $P_{kp.H} = 50$ kN;

$P_{kp\ max} / q = 52,8/1,7 = 31$ κ kN H – class 3; nominal tractor traction effort – $P_{kp.H} = 30$ kN;

$31/1,7 = 18,2$ kN – class 1,8; nominal tractor traction effort – $P_{kp.H} = 18$ kN;

$18,2/1,7 = 10,7$ kN – class 1,1; nominal tractor traction effort – $P_{kp.H} = 11$ kN;

$10,7/1,7 = 6,3 \approx P_{kp\ min}$ – class 0,6; nominal tractor traction effort – $P_{kp.H} = 6$ kN.

Knowing the nominal tractive effort of a tractor of one class or another, you can calculate its operating mass

M_{mp} [10]:

$$M_{mp} = \frac{P_{kp.H} \cdot (1 + 3 \cdot V_x)}{g} \cdot \sqrt{\frac{a}{f \cdot (1 + b)}}, \quad (7)$$

where V_x – coefficient of variation of the variations of the traction load of the power tool; g – Acceleration of gravity.

From expression (7) we find that

$$P_{kp.H} = K \cdot M_{mp}, \quad (8)$$

$$\text{where } K = \frac{g}{1 + 3 \cdot V_x} \cdot \sqrt{\frac{f \cdot (1 + b)}{a}}.$$

Expression (8) makes it possible to set the tolerance to the nominal tractor traction effort. That is, such a range is significant for this value, which allows one or another energy to be attributed precisely to the pulling class, and not to another.

As shown by the analysis of calculations according to expression (8), the nominal traction effort of a tractor of a traction class for its functioning on agrotechnical backgrounds, "stubble" and "field prepared for sowing" in most cases varies within $P_{kp.H-10}^{+20}$ · Value $P_{kp.H}$. At the same time it is equal to the powertrain multiplied by 10 traction class.

Taking into account the foregoing in Table. 2 presents the variant of a new type of agricultural tractors for Ukraine.

2. The type of agricultural wheeled tractors for Ukraine

№	Tracti on classc	Nominal traction effort, P_{kpH} (kN)	Admission to nominal traction effort, kN	Base model tractor	Producer
1	0,6	6	5.4 – 7.2	KIY-440	Ukravtozapchast
2	1,1	11	9.9 – 13.2	KhTZ-3512	KhTZ
3	1,8	18	16.2 – 21.6	YuMZ-8040/8240 KIY -14800	PMZ Ukravtozapchast
4	3	30	27.0 – 36.0	KhTZ -17221 KhTZ -16131	KhTZ
5	5	50	45.0 – 60.0		

The analysis of this table shows that the new type of tractors in the vast majority can be realized on the domestic material and technical base. It is based on the Kharkiv Tractor and Southern Machine-Building (Dnipro) factories. Certain hopes can be put on LLC "Ukravtozapchast" (Kiev).

An exception to the type is only traction class 5. Although to some extent it can be represented by crawler tractors of domestic production KhTZ-181 or KhTZ-280T, the results of practical tests which confirm at least the technical feasibility of such a solution.

The presence of a tractor type with a nominal pulling force of 6 to 50 kN does not mean the absence of a need for power tools with other traction capabilities. Obviously, owners of private plots will need motor-block designs with traction effort at the level of 2-4 kN. In spite of their non-system status, they also require the development of their respective aggregation system. But this task, despite its importance, is secondary compared to the problem of the creation of a domestic System of Machines based on the type of tractor shown above for Ukraine.

Conclusions

Based on the application of new methodological approaches to the definition of the minimum ($P_{кр\ min}$) and maximum ($P_{кр\ max}$) meaning the entire operating range of traction efforts of tractors, the linear nature of changes in their hitching from developed traction effort, it has been established that a new type of wheeled tractors for Ukraine should constitute power means of five traction classes: 0.6; 1.1; 1.8; 3 and 5. The increase of each of these figures is exactly 10 times the nominal tractor traction effort ($P_{кр.н}$) in kN. The range of this parameter change for each power means of a pulling class varies within $P_{кр.н-10}^{+20}$.

The proposed type of tractors with the exception of the traction class 5 is practically implemented on the basis of those models of energy products manufactured at the Kharkiv Tractor and Southern Machine-Building Plant (Dnipro) plants, as well as LLC "Ukravtozapchastna" (Kyiv).

The problem of tractors of traction class 5 can be solved either by the purchase of such energy resources abroad, or by the use (where appropriate and possible) of crawler tractors of the domestic production of the brands KhTZ-181 and HTZ-280T.

References

1. *Trepnenkov I.I.* Operational indicators of agricultural tractors / I.I. Trepnenkov. - M.: State scientific and technical. pub. machine-building literature, 1963. - 272 s.
2. *Yushin O.* Prospects for the development of tractor energy / O. Yushin // Mechanization of agriculture. Vip.- K.: Urojai, 1979. - 7.
3. *Pojidaev S.P.* To the improvement of the method of assigning tractors to the traction classes / S.P. Pojidaev // Mechanization of agriculture. - K.: Urojai, 1994. - Vip.79.
4. *Nadykto V.* Energy-Saving Tractors and Its Implementation / V.T. Nadykto // Engineering and Technology of Agroindustrial Complex, 2011, №9.
5. *Nadykto V.T.* The role of energy saturation of tractors in the formation of their type / V.T. Nadykto // Tractors and agricultural machines, 2012, №3.
6. *Adamchuk V.V.* Ukraine needs its own type of tractor / V.V. Adamchuk, V.M. Bulgakov, V.M. Kyurchev, V.T. Nadykto // Agrarian Week, 2014, №14.
7. *Williams V.R.* Soil science. Agriculture with the fundamentals of soil science / V.R. Williams. 448 s- M.: OGI-Z-SELHOZGIZ, 1940. -.
8. *Nadykto V.* Determination of maximum stacking of wheeled engines with allowance for the restriction of their pressure on the soil / V. Nadykto // Machinery and Technologies of the Agroindustrial Complex, 2014, No. 7.
9. *Bulgakov V.* Investigation of draft coefficient of wheeled tractor / V. Bulgakov, V. Nadykto, I. Velichko, S. Ivanovs // Engineering of rural development (Proceedings), 2016. - Volume 15. - pp.
10. *Adamchuk V.* Development of a new method for determining the main parameters of an agricultural tractor / V. Adamchuk, V. Bulgakov, V. Nadykto, Ye. Ihnatyev // Engineering and technology of agrarian and industrial complex, 2016, №10.