THEORETICAL STUDY TO DETERMINE THE STANDARD SIZE RANGE OF AGRICULTURAL TRACTORS

Prof. Eng. Bulgakov V.[1] PhD., Prof. Eng. Kyurchev V.[2] PhD., Prof. Eng. Nadykto V.[2] PhD.,
Corresp. Member Prof. Eng. Beloev H.[3], DHC, Prof. Eng. Kangalov P.[3], PhD, Assos. prof. Eng. Mitev G.[3], PhD

[1]National University of Life and Environmental Sciences of Ukraine, 15, Heroyiv Oborony Str., Kyiv, 03041, Ukraine;
[2]Tavria State Agrotechnological University, 18, Khmelnytskoho pr., Melitopol, 72312, Zaporozhye region, Ukraine;
[3]"Angel Kanchev" University of Rousse, 8, Studentska Str., 7017 Ruse, Bulgaria

Abstract: *Since the tractor is the main energy source in agriculture, the state with highly developed agrarian production, tractor and agricultural machine building should have a fairly clear and consistent policy in the field of organizing the production and supply to agricultural producers of a wide range of tractors for various purposes. Such a policy is based on the type of mobile energy resources, i.e. tractors, based on a deep analysis and study of the volume of agricultural production, the needs for mechanized technologies, the theory of the operation of agricultural machines, the overall assessment of the development of high-tech agriculture. The purpose of this study is to develop theoretical bases for calculating the type of agricultural tractors based on an optimization of technical and economic analysis, taking into account the need for a qualitative and timely implementation of the entire closed set of works in agricultural production. During the research methods of machine use in agriculture, higher mathematics, economics, compilation of programs and numerical calculations on PC were used. The results of the study showed that the classification of tractors should be carried out not according to traction power (as is done in most countries of the world), but by the nominal traction force developed by them. It has been established that this gives a more accurate representation of the operational properties of an energy tool, which in turn allows for the very accurate and correct selection of complexes of appropriate agricultural machinery and implements for its effective operation. The presented theoretical approaches allow to determine with a high degree of accuracy the type of agricultural tractors for any country.*

KEY WORDS*: AGRICULTURAL PRODUCTION, TRACTOR, TYPE, TRACTIVE POWER, OPERATION, TRACTIVE EFFORT.*

1. Introduction

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

2. Results and discussion

The type of tractors is usually called the aggregate of all their models (including modifications), compiled on the basis of optimization of technical and economic calculations, taking into account the need for high-quality and timely performance of a set of works in the national economy of the country.

A promising fleet of tractors, based on their standard size range, is the main reference material in selecting design parameters and creating a new model of the power facility. All prospects for the use of agricultural tractors as a mobile energy source, the appearance of energy resources of non-traditional layout schemes, etc., require constant specification of their type

In the past, we adopted the type of agricultural tractors according to their destination and the traction class. According to the first classification – it's tractors of general purpose, universal-tilled, specialized and small-sized.

Tractors of general use are used for soil cultivation, fertilization, sowing and harvesting of agricultural crops. Cultures and the like.

Universal-tilled tractors are mainly intended for cultivating tilled crops. Can be used on transport and other robots.

Specialized tractors are designed to perform work on growing and harvesting individual crops: beets, grapes, rice, vegetables, etc. In practice, these tractors, as a rule, are modifications of the basic models of general and universal-tidal power equipment.

Small tractors can be used on all types of agricultural work.

Accordingly, the former GOST 27021-86 or ST SEV 628-85 standard agricultural tractor series included 10 traction classes. As can be seen from Table 1, it was an increasing sequence of dimensionless numbers (0.2...8.0), each of which expressed the value of the nominal tractor pulling force (Pdb) in the tones, since the formation of the type originated as early as the old system of measuring physical values.

Table 1 – Ratio between traction classes and categories of tractors

№	Traction class	Nominal pulling force (P_{db}, кN)	Basic model		Power category and traction power ($N_{db.max}$, kWt) (ISO 730/1 and 730/3-82)
			Model	Engine power (N_e, kWt)	
	GOST 27021-86 (ST SEV 628-85)				
1	0.2	1.8…5.4			I – 25
2	0.6	5.4…8.1	T-25	18.4	
3	0.9	8.1…12.6	T-40	36.8	II – 30…70
4	1.4	12.6…18	MTZ-80	55.3	
5	2	18…27	T-70S	51.5	
6	3	27…36	T-150K	121.5	III – 70…135
7	4	36…45	T-4	80.9	
8	5	45…54	K-700	161.8	IV – 135…300
9	6	54…72	T-130	116.2	
10	8	72…108	K-710	220.5	

According to the plan, the values of P_{db} (in kN) should represent such a geometric progression, the denominator of which (q) would be determined from the following relationship [9]:

$$q = \sqrt[n-1]{\frac{Pdb_{max}}{Pdb_{min}}}\,, \tag{1}$$

where: P_{dbmax}, P_{dbmin} – the upper and lower limit of the entire operating range of traction forces of tractors; n is the number of terms in the series (traction classes).

It is assumed that with a rationally designed standard size range, the intervals between the traction ranges of adjacent tractor classes should be absent, the ranges themselves are identical, and the denominator of the progression q is equal to the ratio (r) of the maximum ($P_{\max}$) and minimum ($P_{\min}$) traction forces of the same Traction rang, i.e.

$$q = r = P_{\max}/P_{\min}\,. \tag{2}$$

In international practice, in accordance with ISO 730/1 and 730 / 3–82, the classification of tractors according to the maximum tractive power $N_{db.max}$, obtained when testing the power facility on a smooth horizontal and dry concrete surface, or a surface covered with beveled / uncut grass, is used. Tractors are divided into four categories, each corresponding to the classification of energy resources in accordance with the international standard GOST 27021-86 (ST SEV 628-85, see Table 1).

The long-term practice of recent years shows that the classification according to GOST 27021–86 (ST SEV 628–85) gives a more accurate representation of the tractor's operational properties. And this, in turn, allows you to correctly pick up a complex of agricultural machines and tools. For example, at one time the Minsk and Vladimir Tractor Plants produced tractor class 2 tractors (MTZ-142 and LTZ-145, respectively) with a maximum traction power of about 95 kW. If only the ISO classification is used (Table 1), then it is possible to conclude incorrectly that MTZ-142 and LTZ-145 could work with a train of machines intended for tractors of traction classes 3 and 4.

At the same time, the tractor of traction class 6 (T-130) according to traction power belonged to group III of ISO-730/1 standard. It turns out that it could effectively be aggregated with tools to the energy facilities of significantly lower traction classes 3 and 4 (see Table 1).

One more example. In 1998, 650 tractors “John Deer-8940” were purchased for the needs of Ukraine's agriculture [10]. Based on the power of their engines (200 kW) and the ISO classification (see Table 1), it was assumed that they would be used with tools intended for class 5 tractors (K-700, K-701). In practice, this was not possible, because the traction and coupling properties of the “John Deer-8940” occupy an intermediate position between the energy facilities of traction classes 3 and 4.

Another thing is that the real type of tractors, which formally acts on the localities of the CIS countries, is now created, as the researchers have repeatedly emphasized [3, 4, 7], with significant deviations from the above requirements (2). In the direction of its improvement, first of all, it would be necessary to clarify the methods of determination:

– the operational weight of the tractor;
– nominal tractive effort and tolerance to its fluctuations;
– the width of the traction effort range of the tractor;
– the rate of slipping of the power source when determining its nominal;
– tractive effort.

Moreover, an effective standard-sized line of tractors should be created taking into account the technical and economic performance of machine-tractor units based on them [1, 2, 5]. Due to the implementation of one of the attempts of this approach, it was found that for tractors of seven traction classes, for our country's economy, taking into account their specialization, zonal features and the structure of cultivated areas, it is enough: 0.2; 0.6; 1.4; 2; 3; 5 and 6 [11]. It is interesting that a similar conclusion was reached by those scientists who considered the question of specifying the type of tractors both for the conditions of the USSR [4] and for the current conditions in Russia [8]. In the first case, the size range of power tools should have the following form: 0.4; 1.1; 1.8; 2.5; 4; 5.5; 7, and in the second – 0.4; 0.7; 1.1; 1.8; 3; 5 and 7.

In comparison with [11], these types, although new, but they, in our opinion, are not devoid of shortcomings [because of inconsistency with condition (2), for example].

As for the type proposed in [11], we can say the following about him. First, tractors of traction class 6 are designed for road construction, meliorative, plantation and excavation works. The determination of their quantity can be carried out by a separately developed method. Nevertheless, as a basic model of tractors of this traction class, it is possible to adopt the caterpillar energy facility TS-10, which is currently produced by JSC “KhTZ”.

Secondly, JSC “KhTZ” Tractor Works has mastered the production of tractors of the KhTZ-160 series, which, being power tools of traction class 3, can be used quite efficiently with a set of machines and implements intended for cultivating tilled crops by tractors of traction class 2 [6].

Therefore, if we do not aim to develop an entirely new type of tractors, then for Ukraine it could include power supplies of 6 traction classes: 0.2; 0.6; 1.4; 3; 5; 6.

Producers of this product are Kharkov (KhTZ) and Dnepropetrovsk (YuMZ) tractor plants (Table 2). As a compromise option, we can consider the production of new tractors of traction class 1.4 (KIY-14102) limited liability company LLC Ukravtozapchastina (Kiev).

Table 2 – Basic models of tractor type of Ukraine

Tractor class	Basic model	Productivity
0.2	KhTZ-1211	JSC “KhTZ”
0.6	KhTZ-3510/3522	JSC “KhTZ”
1.4	YuMZ-8040/8240 KIY-14102	YuMZ (Dnepropetrovsk) LTD “Ukravtozapchastina”
3.0	KhTZ-16131, KhTZ-17221, T-150-05-09	JSC “KhTZ”
5.0	KhTZ-181	JSC “KhTZ”
6.0	TS-10	JSC “KhTZ”

It is known that the type of domestic tractors, presented in Table 1, is not without the disadvantages mentioned above. Moreover, the energy facilities presented in it are characterized by a rigid parametric relationship between their service weight ($G_т$) and engine power (N_e):

$$E_T = N_e/G_т = const, \quad (3)$$

where: E_T – energy of the tractor, kW / t.

Every type of energy means needs to develop an appropriate system of aggregation, which would ensure:

– Increase of productivity of work;
– reduction of energy costs and materials;
– Reduction of harmful impact on the environment;
– high versatility and employment throughout the year;
– the necessary reliability and level of unification.

At the present stage of the development of the society, it is impossible to satisfy these requirements within the old traction concept of building energy resources. The fact is that the development of tractors in accordance with the traction concept (3) was and in many cases is now due to the need to realize engine power only through tractive effort. After all, if N_e exceeds the corresponding value of $G_т$, then it (N_e) will not be used for traction operations. If the engine power deviates in the opposite direction, the tractor will operate at reduced working speeds and the tractor unit based on it will not develop the expected performance.

The modern development of mobile energy resources all over the world occurs within the framework of the new traction-energy concept. The essence of this is that the power of the tractor engine and its operating weight are not related by a rigid (as before) parametric dependence. Those:

$$E_T = N_e/G_T = var. \quad (4)$$

At the same time, the value of N_e increases according to current technological requirements, the value of $G_т$ increases only for the sake of ensuring the appropriate strength and safety of the tractor construction. As a result, the energy saturation increases and in many cases already significantly exceeds 20 kW/t. This makes it possible to effectively use such tractors as part of traction-drive units, in the implementation of no-till systems, the creation of perspective modular power devices of variable traction class (MES), and so on.

It should be noted that the work on the creation of MES went beyond research, and the results confirmed the hypothesis of technical feasibility and economic feasibility of their development and implementation in Ukraine [6]. MES can be fully considered as components of a new domestic type of tractors

Determination of the required number of tractors can be carried out taking into account the peculiarities of the natural and climatic zones of our country, the size of the acreage of agricultural crops, the specialization of farms, the new technologies used, and so on. For each of the zones, the number of tractors of a traction class (N_i) can be determined from the expression:

$$N_i = K_i \cdot S_i \cdot (1000)^{-1}, \quad (5)$$

where: K_i – specification of the need for tractors of the corresponding traction class per 1000 hectares of arable land or the area of sowing of a particular crop; S_i – total area of crops or arable land.

The complexity of the calculations is precisely in determining the specifications of the need for tractors of one or another traction class for each of the natural and climatic zones of the country. Existing nowadays similar specifications need a significant refinement, since they are designed for tractors of the old traction concept.

Centrally, such work can be performed by scientific research institutions of the National Academy of Sciences. But it can be done only when the type of tractors is finally adopted (determined) in Ukraine.

In conclusion, we should say the following. Adoption of the tractor type will allow to create in the country the corresponding System of Machines, which is now unordered. The reason for this state of things is as follows.

Abroad many firms together with tractors let out also the complex of agricultural machines and tools adapted to them. In this case, it is not very important to what tractive class energy means are, because their traction-energy indicators meet the requirements of the technological part of the AIT with which they are being aggregated.

In Ukraine, however, tractors are produced by one firm, and agricultural tools and machinery by others. If both the first and the second are not within the limits of the relevant constraints (requirements) in the design of their products, in principle, one can get a situation where a good tractor and a good agricultural machine / tool together can give an insufficiently good machine and tractor unit.

3. Conclusions

The first step in the implementation of the country's own traction program is the adoption of a mobile energy type.

Classification of tractors in Ukraine should be carried out not by traction capacity (as it is done abroad), but by nominal tractive effort. The practice of recent years shows that this gives a more precise concept of the operational properties of the energy facility and, in turn, allows the correct selection of a set of appropriate agricultural machinery and tools.

The basis of the domestic type of tractors should be represented by mobile energy resources of the traction-energy concept. The necessary material and technical basis for their development and implementation in Ukraine is 1912/5000.

4. Literature

1. Kambulov S.I. Obosnovaniye struktury MES sel'skokhozyaystvennogo naznacheniya /S.I. Kambulov //Traktory i sel'skokhozyaystvennyye mashiny. – 2008. – №3.
2. Ksenevich I.P. Ob ekonomicheskikh aspektakh obosnovaniya tipazha s.-kh. traktorov / I.P. Ksenevich // Traktory i sel'skokhozyaystvennyye mashiny. – 1985. – №5.
3. Ksenevich I.P. O sovershenstvovanii klassifikatsii sel'skokhozyaystvennykh traktorov / I.P. Ksenevich, V.I. Mininzon, A.P. Parfenov // Traktory i sel'skokhozyaystvennyye mashiny. – 1989. – №10.
4. Ratsioal'nyy tiporazmernyy ryad perspektivnykh sel'skokhozyaystvennykh traktorov / I.P. Ksenevich, M.I. Lyasko, V.I. Mininzon, A.P. Parfenov // Traktory i sel'skokhozyaystvennyye mashiny. – 1990. – №11.
5. Kut'kov G.M. Perspektivnyy tipazh sel'skokhozyaystvennykh traktorov dolzhen byt' optimal'nym / G.M. Kut'kov, V.I. Mininzon // Mekhanizatsiya i elektrifikatsiya sotsialisticheskogo sel'skogo khozyaystva. – 1967. – №1.
6. Noví mobíl'ní yenergetichní zasobi Ukraîni . Teoretichní osnovi vikoristannya v zemlerobství: navch. posíbnik / V.T. Nadikto, M.L. Krizhachkívs'kiy, V.M. Kyurchev, S.L. Abdula. – Melítopol': MMD. – 2006. – 337 s.
7. Pozhidaêv S.P. Do udoskonalennya metodiki vídnesennya traktorív do tyagovikh klasív / S.P. Pozhidaêv // Mízhvídomchiy tematichniy naukovo-tekhníchniy zbírnik. – K., 1994. – Vip. 79.
8. Surayev N.G. Optimal'nyy tipazh sel'skokhozyaystvennykh traktorov na osnove virtual'nogo tiporazmernogo ryada / N.G. Surayev // Traktory i sel'skokhozyaystvennyye mashiny. – 2000. – №11.
9. Trepenenkov I.I. Ekspluatatsionnyye pokazateli sel'skokhozyaystvennykh traktorov / I.I. Trepenenkov. – M.: Gosudarstvennoye nauchno-tekhnicheskoye izdatel'stvo mashinostroitel'noy literatury, 1963. – 272 s.
10. Frosevich L. Kak kota v meshke kupila Ukraina shestikolesnyy traktor / L. Frosevich // Kiyevskiye Vedomosti. – 1999. –22 yanv.
11. Yushin O. Perspektivi rozvitku traktornoî yenergetiki / O. Yushin // Mekhanízatsíya síl's'kogo gospodarstva. – 1979. – №7.

Bibliography:

1. Kambulov S.I. Substantiation of the structure of agricultural MES / SI. Kambulov // Tractors and agricultural machinery. – 2008. – №3.
2. Ksenevich I.P. On the economic aspects of the justification of the type of farming. Tractors / I.P. Ksenevich // Tractors and agricultural machinery. – 1985. – №5.
3. Ksenevich I.P. On the improvement of the classification of agricultural tractors / I.P. Ksenevich, V.I. Mininzon, A.P. Parfenov // Tractors and agricultural machinery. – 1989. – №10.
4. Rational series of a number of promising agricultural tractors / I.P. Ksenevich, M.I. Lyasko, V.I. Mininzon, A.P. Parfenov // Tractors and agricultural machinery. – 1990. – № 11.
5. Kutkov G.M. Prospective type of agricultural tractors should be optimal / G.M. Kutkov, V.I. Mininzon // Mechanization and electrification of socialist agriculture. – 1967. – №1.
6. New mobile power means in Ukraine.Theoretical foundations in the field of earthquakes: Handbook / V.T. Nadykto, M.L. Krizhachivsky, V.M. Kurchev, S.L. Abdula. – Melitopol: MMD. – 2006. – 337 p.
7. Pozhidaev S.P. Up to the up-to-date methodology of the uptake of tractors to tractors of classes / S.P. Pozhidaev // Interdepartmental thematic scientific and technical collection. – K., 1994. – Vol. 79.
8. Suraev N.G. Optimum type of agricultural tractors on the basis of a virtual type-size series / N.G. Suraev // Tractors and agricultural machinery. – 2000. – № 11.
9. Trepenenkov I.I. Operational indicators of agricultural tractors / I.I. Trepenko. – M.: State Scientific and Technical Publishing House of Machine-Building Literature, 1963. – 272 p.
10. Frosiewicz L. As a cat in a sack bought Ukraine six-wheeled tractor / L. Frocevich // Kievskie Vedomosti. – 1999. – 22 Jan.
11. Yushin O. Perspective of the development of the tractor power industry / O. Yushin // Mekhanizatsiya sylskogo gosartarstva. – 1979. – № 7.