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TRANSLATION
ON THE NOMINAL TRACTIVE EFFORT
OF AN
AGRICULTURAL DEPARTMENT TRACTOR
By
AMSTA - RR(FIO)

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EDITED TRANSLATION
(from Russian)

Title: ON THE NOMINAL TRACTIVE EFFORT OF AN AGRICULTURAL
DEPARTMENT TRACTOR

By: A. P. Parfenov (NATI)

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ON THE NOMINAL TRACTIVE EFFORT OF AN AGRICULTURAL DEPARTMENT TRACTOR

By A. P. Parfenov (NATI)

Beginning in 1956, the NATI worked out a classification of tractors according to their nominal tractive effort which is based on a parameter determining the possibility for equipping the tractor with agricultural department lugs and equipment which have a suitable tractive resistance. In principle, the same construction is accepted as for the SEV "tractor system".

The classifying parameter which was adopted is sufficiently dependable, regardless of the increase of operating speeds and engine horsepower. The most important factor in developing a prospective tractor type and for the solution of practical problems is an accurate formulation of a concept of nominal tractive effort and the formulation of a rational method for determining its value.

Various methods for determining the nominal tractive effort of an agricultural department tractor are presently being proposed. The most generalized of these is the proposition that nominal tractive effort of a department of agriculture tractor can be determined by characteristics on a stubble field of normal density and moisture.

In the case of the method proposed on the basis of the present tractor type, the nominal tractive effort P_n can be determined by the permissible amount of decline in tractive efficiency relative to its maximum value $\eta_T^{\max}$ and by the permissible slip of the engine.

Subsequently, values of tractive efficiency and slip determining P_n were improved on the basis of more ideal methods determining the zone $\eta_T^{\max}$ (2).

Some experts consider that for nominal tractive effort, traction must be assumed at $\eta_T^{\max}$ (3).

The opinion has also been expressed that the "nominal" must also take into account the tractive effort of the tractor at which the maximum efficiency of the tractor aggregate is guaranteed during the fulfillment of more widespread operations (4) for the given type of agricultural department tractor.

The disadvantages of determining nominal tractive effort P_n of a tractor according to maximum tractive efficiency are the following:

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- a) Very low accuracy (20-30%) in determining the abscissa of this maximum for tracked vehicles and tractors with four drive wheels, for which the dependence of η_T on the tractive effort P_{kp} has a slanting character in a wide range P_{kp} ;
- b) The system of maximum tractor efficiency is not entirely the system of maximum efficiency of agricultural department tractors (4);
- c) The method $\eta_T^{\max}$ of the same tractor shifts in a range of high speeds and low tractive efforts (5) with an increase of the level of energy absorption which is witness to the failure of the stability requirement produced by the basic classifying parameter.

The method of determining P_x according to the permissible decrease of $\eta_T^{\max}$ (3) is more satisfactory than the method of determining P_x according to $\eta_T^{\max}$ and has none of the disadvantages of the preceding (see a and b).

The methodical approach for determining P_x according to the system of maximum efficiency of the tractor aggregate takes into account the parameters of agricultural machines and equipment, the balance of time of primary use, as well as the level of energy absorption characteristic for the present stage of technological development. Under these circumstances, the classifying parameter loses its primary simplicity, definitiveness and stability. It is possible to arrive at the ridiculous conclusion that the same tractor, when used on arable land, will concern one type of traction, another type will be involved when the tractor is used for transport and still another when it is used for cultivation. The realization of a system of maximum efficiency of an agricultural aggregate is practically impossible because of the inadmissibility of high slip values from an agro-technical point of view (4). Once again, the determination of P_x involves the determination of a permissible level of tractor slip.

The dependence of slip on tractive effort is a reliable indication of the coupling characteristics of a tractor of a given type and class on a given soil base. Thus, a valid limit of slip with sufficient accuracy for purposes of classification characterizes the tractive potential of tractors.

Consequently, the determination of nominal tractive effort of a tractor according to the permissible level of slip of its engine is, from our point of view, the more correct approach.

At the same time, it is necessary to indicate the limit values of slip for an agricultural tractor by an arbitrary choice (20% for wheeled tractors and 7% for those with tracks) which are accepted for a characteristically nominal tractive effort of tractor types for the years 1966-1970.

The common disadvantage of all methods proposed for determining nominal tractive effort is that they do not indicate the type of soil on which the nominal tractive effort of a tractor must be determined. In the meantime, studies have shown that the tractive efforts of tractors are quite different on soils of different structure and composition (6).

The results of a large number of traction studies were analyzed from tests carried out at various machine testing centers for the purpose of deriving permissible slip values.

Certain dimensionless characteristics were accepted as criteria for evaluating the tractive properties of tractors of various types on various soil types: coefficient of coupling utilization equal to the ratio of tractive effort on the hook to the adhesion weight of the tractor with consideration of the dynamic redistribution of normal soil reactions and the coefficient of engine slip δ .

The tractive effort of a tractor with two drive wheels can be expressed by its operating weight:

$$P_{\kappa p} = \lambda G \varphi_{\kappa p}, \quad (1)$$

where G , λ -- is the operating weight of the tractor and the part of it exerted on the drive wheel in operating condition; $\varphi_{\kappa p}$ is the coefficient of utilization of coupling.

For a wheeled tractor with all drive wheels and a tractor with tracks:

$$P_{\kappa p} = G \varphi_{\kappa p}. \quad (2)$$

Assuming that the tractive effort is exerted horizontally, coefficient λ can be expressed by the tractor parameter

$$\lambda = \frac{L-a}{L} + \frac{P_{\kappa p}}{G} \cdot \frac{h_{\kappa p}}{L}, \quad (3)$$

where L is the base and horizontal coordinate of the center of gravity of the tractor; h_{kp} is the vertical coordinate point of the trailer.

From Eq. (1) and Eq. (3) it follows that:

$$\lambda = \frac{L-a}{L-q_{kp}h_{kp}}. \quad (4)$$

Tractive power can be limited by two factors: engine power and the coupling of the engine with the soil. For a tractor used in the capacity of a pulling machine in a system of relatively slow operating speeds, the coupling factor is limited.

Thus the energetically permissible slip limit of tractors is useful for determining a result of the optimal utilization of adhesion weight.

The expression characterizing the tractive power of a wheeled tractor 4 X 2 may be presented in the following form:

$$N_{kp} = P_{kp}v = \lambda G q_{kp} (1-\eta) v_T, \quad (5)$$

where v_T , -- is the calculated speed and slipping of the tractor or, with consideration of Eq. (4):

$$N_{kp} = \frac{q_{kp}(L-a)}{L-q_{kp}h_{kp}} G (1-\eta) v_T. \quad (6)$$

For a wheeled tractor with four drive wheels and a tracked tractor ($\lambda = 1$) the tractive power is expressed by the relation:

$$N_{kp} = G q_{kp} (1-\eta) v_T. \quad (7)$$

Eqs. (6) and (7) show that at a given value of operating weight and theoretical tractor speed, a larger value of tractive power, according to the conditions of the engine coupling with the soil, is attained at maximum value of parameter A for wheeled tractor 4 X 2:

$$A = \frac{q_{kp}(L-a)}{L-q_{kp}h_{kp}} (1-\eta) \quad (8)$$

and parameter B for wheeled tractor 4 X 4 and tracked tractor:

$$B = q_{kp} (1-\eta). \quad (9)$$

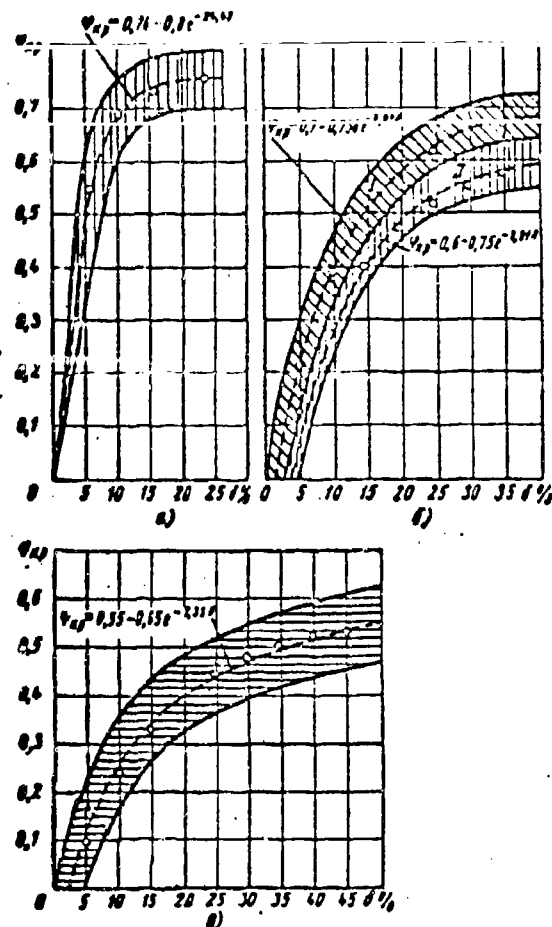


Fig. 1. General dependences of φ_{kp} on δ for wheeled tractors 4 X 2: a - dry concrete; b - stubble field of barley or winter wheat on black dirt, loam (I) and sandy soil (II); c - field prepared for sowing, on black dirt and loam.

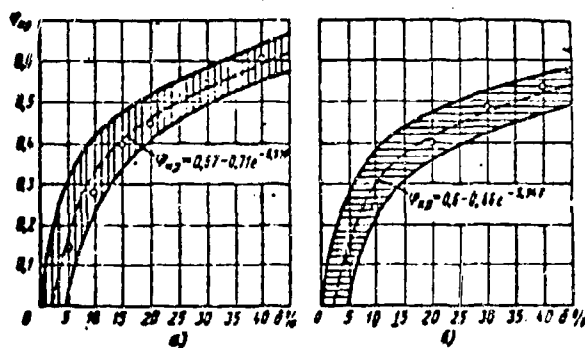


Fig. 2. General dependences of φ_{kp} on δ for wheeled tractors 4 X 4; a - stubble field of wheat on black dirt and loam; b - field prepared for sowing, on black dirt and loam.

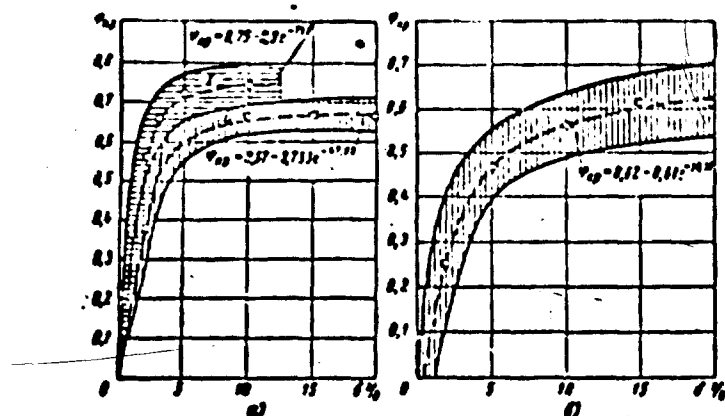


Fig. 3. General dependences of φ_{kp} on δ for tracked tractors; a - stubble field of wheat and barley on heavy loam and medium loam black dirt (I-data of the KNIITIM; II-data of the No. Cau. Institute); b - field prepared for sowing on black dirt.

The determination of permissible limits of slip for tractors involves the determination of parameters A and B applicable to general characteristics of the tractor on various types of soil bases.

It should be noted that the permissible limits of slip for a wheeled tractor which will be acceptable in types from 1966-1970 is also established as the result of the maximum value of tractive power with respect to coupling. However, we did not take into account the factor of dynamic redistribution of vertical soil reactions which are exerted on the front and rear wheels of the 4 X 2 tractor. Nevertheless, the maximum tractive power with respect to coupling is determined according to individual traction characteristics and not on the basis of general traction characteristics for a large number of tractors.

Figs. 1-3 present the general dependences φ_{kp} on δ for wheeled tractors 4 X 2, 4 X 4 and tracked tractors, obtained in the processing of the results of traction experiments.

The hatched regions mark the dissemination limits of points φ_{kp} within the limits of which field the value of φ_{kp} is primarily distributed in accordance with the values of relative soil moisture on which the traction tests were conducted. Moreover, stubble fields with a large value of relative moisture correspond to smaller values of φ_{kp} , but for soils prepared for sowing, the values of φ_{kp} increase with an increase of humidity.

The general dependences approach the characteristics of tractors on a suitable soil base and soil type at normal moisture values.

Thus, for example, the general curve of the characteristics of 4 X 2 tractors on wheat and barley stubble fields and on a field prepared for sowing is characterized by soil humidity at a depth of 15 cm within the limits of 18-25%.

Curves of general tractor characteristics on various soil bases are satisfactorily approximated by a function of the form:

$$\eta_{kp} = \eta_{kp \max} - ae^{-bx}. \quad (10)$$

A similar characteristic function is used in studies (7, 8) to express the dependence of soil resistance to displacement on deformation, which is shown by the connection of tractive characteristics of the tractor with physical-mechanical soil properties.

Coefficients of approximate functions of general characteristic curves for tractors of various types are presented in Table 1.

Values φ_{kp} , calculated according to Eq. (10) are plotted in the form of points on Figs. 1-3.

For tractors with all guide wheels, generalizations are made on the basis of the characteristics of 4 X 4 tractors with dissimilar front and rear wheels, for which a wide range of material is available. According to the amount of necessary data accumulated with respect to tractors with all guide wheels of a single dimension, the coefficients presented in Table 1 will be narrowed down with consideration of a method of differentiation for evaluating the traction characteristics of 4 X 4 tractors having different components.

The nominal tractive effort of an agricultural tractor is best characterized by slip values at which the functions $A(\delta)$ and $B(\delta)$, applicable to the general characteristic curves for a tractor, reach maximum values (Fig. 4). Moreover, it is necessary to take into account the negative scattering of the points of relations $\varphi_{kp} = f(\delta)$ which allows us to take in the entire zone of optimum values of slip (according to the utilization of tractor adhesion weight).

The energetic optimum values of tractor slip δ_{opt} at which the functions $A(\delta)$ and $B(\delta)$ have maximum values are presented in Table 1. With the calculation $A(\delta)$ we assume the following constructional parameters corresponding to the MTZ-50 tractor: $L = 2.35$ m, $a/L = 0.377$; $h_{kp} = 0.48$ m.

Table 1

Tractor Type	Soil base, Soil Type	$\phi_{kp} = \phi_{kpmax} - ae$			ϕ_{opt} in %
		a	b	ϕ_{kpmax}	
Wheeled, 4 X 2	Concrete	0.8	24.4	0.76	14
	Wheat and barley stubble field, on black dirt and loam	0.756	8.82	0.7	25
	Wheat and barley stubble field on sandy soil	0.75	8.81	0.6	25
	Field prepared for sowing (black dirt and loam)	0.65	7.35	0.55	27.5
Wheeled, 4 X 4	Wheat and barley stubble field on black dirt and loam	0.71	5.87	0.67	27.5
	Field prepared for sowing (black dirt and loam)	0.66	5.94	0.6	27.5
Tracked	Wheat and barley stubble field on heavy loam black dirt (data of KNIITIM)	0.8	73	0.75	6
	Wheat and barley stubble field on medium loam black dirt (data of No. Cau. Machine Testing Institute)	0.753	47.6	0.67	8.5
	Field prepared for sowing (black dirt with medium and heavy loam)	0.68	30.3	0.62	11.5

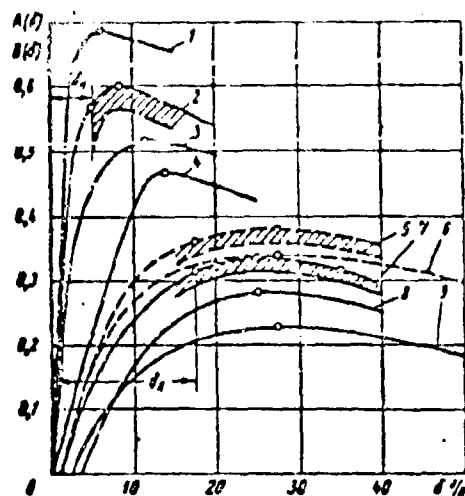


Fig. 4. Dimensionless functions $A(\delta)$ and $B(\delta)$ for tractors of various types on various soils: — wheeled 4 X 2; --- wheeled 4 X 4; -- tracked; 1 - stubble field, black dirt with heavy loam; 2 - stubble field, black dirt with medium loam; 3 - after sowing; 4 - dry concrete; 5 - stubble field, black dirt, loam; 6 - after sowing; 7 - stubble field, black dirt, loam; 8 - stubble field, sandy; 9 - after sowing.

Table 2

Tractor Type	Characteristics at Nominal Tractive Effort	
	δ_n in %	φ_{kp}
Wheeled 4 X 2	17.5	0.54
Wheeled 4 X 4	17.5	0.43
Tracked	5	0.6

Fig. 4 illustrates tests for wheeled tractors on stubble fields of black dirt and loam as well as for tracked tractors on stubble fields with medium loam black dirt; the deviation boundaries of the relations $A(\delta)$ and $B(\delta)$ are plotted with consideration of the negative scattering of points φ_{kp} .

Orienting ourselves by the general tractor characteristics on a stubble field with a given soil type and taking into account the negative deviation of relations $A(\delta)$ and $B(\delta)$ at corresponding optimum slip, we can determine the slip values δ_x characterizing the nominal tractive effort. Let us call δ_x the nominal slip. In Fig. 4, the slip values δ_x are determined graphically.

The values of δ_x and the coefficients of coupling utilization φ_{kpx} corresponding to them are presented in Table 2.

An analysis of tractive characteristics shows that at nominal slip values, the nominal tractive efficiency of all types of agricultural tractors makes up about 0.97 of its maximum value.

Assuming that at a nominal tractive effort on the guide wheel of a 4 X 2 tractor, 70% of its operating weight is exerted ($\lambda_x = 0.7$), for the utilization coefficient of operating weight G_x at nominal tractive effort P_{kpx} we obtain

$$\frac{P_{kpx}}{G_x} = \lambda_x \varphi_{kpx} = 0.7 \cdot 0.54 = 0.38 \quad (11)$$

as opposed to 0.43 for a tractor with all drive wheels (Table 2).

The operating weight at nominal tractive effort takes into account the tractor weight when provided with fuel, water and oil, all operating instruments, a driver and ballast furnished by the manufacturer. Thus, for example, according to test certificates, the operating weight G_x of the T-40 and MTZ-50 tractors exceeds their constructional weight by 15-20%.

A tracked tractor is turned by partially or completely disconnecting the driving moment supplied to the lagging track, in accordance with which the turning potential of a tractor is limited by the amount of power delivered at the wheel which is generated only at the leading track. Thus, the value of the coefficient $\varphi_{kpx} = 0.6$ which is selected for a tracked tractor from the condition of its rectilinear movement, must be verified for the purpose of guaranteeing maneuverability.

In accordance with the value $\frac{P_{kpx}}{G_x} = 0.38$ the T-40 and MTZ-50 tractors (equipped, as a rule, with standard agricultural machinery and equipment) can be referred to the 1.1 and 1.2 ton tractive class. Accordingly, at the same time according to a method proposed on the basis of present types, the T-40 and MTZ-50 tractors can be put into the 1.2 and 1.4 ton class.

The viewpoint of (9) is known, according to which in our agricultural economy it is useful to have both wheeled and tracked tractors for plowing, which generated tractive efforts of 0.9 and 1.4 ton (4 X 2 wheeled tractor) and 2 ton (tracked tractor) on the cultivated field with permissible slip.

The relation $\frac{\eta_{\text{npn}}}{\eta_{\text{np}, s_n}}$, where η_{np, s_n} -- is the coefficient of coupling utilization at normal slip s_n on a field prepared for sowing for 4 X 2 tractors on black dirt and loam amounts to 1.45 (Fig. 1), for tracked tractors on loamy black dirt 1.3 (Fig. 3).

For 4 X 2 tractors, due to the possibility of an additional drive wheel load on a cultivated field, we can assume that the ratio of nominal tractive effort to tractive effort on soft soil at nominal slip s_n equals 1.3-1.4. For tracked tractors, we can assume that the indicated ratio equals 1.3. According to these ratios, tractors generating tractive efforts of 0.9 ton, 1.4 ton (4 X 2) and 2.0 tons (tracked) on the cultivated field can be put accordingly in the traction class (1.2-1.3 ton; 1.8-2.0 tons and 2.5 tons (on stubble field).

Conclusions

1. The nominal tractive effort of an agricultural tractor must take into account the tractive effort realized on a stubble field with normal moisture and density on black dirt or clay with 17-18% slip for wheeled vehicles and 5% for tracked vehicles.
2. The nominal tractive effort of a tractor can be determined by the results of traction tests and for planning it can be calculated roughly in accordance with given tractor parameters and the magnitudes η_{kp, s_n} and $P_{\text{kp}, s_n}/G_n$.
3. In accordance with the proposed classification, the series-produced T-40 and MTZ-50 tractors according to our own parameters approach the 1.2 ton traction class (nominal tractive efforts 1.1 and 1.2 ton respectively).

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13. ABSTRACT

A classification of tractors has been worked out according to their nominal tractive effort. It is based on a parameter determining the possibility for equipping the tractor with agricultural department loads and equipment which have a suitable tractive resistance. Various methods for determining the Nominal tractive effort of an agricultural department tractor are proposed.

It was found that the nominal tractive effort of an agricultural tractor must take into account the tractive effort realized in a stubble field with normal moisture and density on black dirt or clay. Also the nominal tractive effort of a tractor can be determined by the results of traction tests. For planning, it can be calculated roughly in accordance with given tractor parameters.

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