Journal of Advanced Zoology

ISSN: 0253-7214

*Volume **44** Special Issue **-02 Year 2023** Page **852:860***

USING AN ANALYTICAL METHOD TO DETERMINE FUEL CONSUMPTION AND MOVEMENT SPEED OF THE MTI.

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Article History

Received: 27Aug 2023

Revised: 28Sept 2023

Accepted: 06Oct 2023

Annotation. To develop standards for production and per-hectare fuel consumption, the speed of the unit and the hourly fuel consumption are determined based on the specified values of the specific resistance of the implements and the typical traction characteristics of the tractor (1). The composition of the unit and its mode of operation when performing a standardized agricultural operation are determined by graphical and graphic-analytical methods, mainly by a method based on a graphical combination of the traction characteristics of tractors and the resistance of machines and implements. (2.5). These methods, although somewhat labor-intensive, make it possible to obtain some averaged data for technical standardization and can be used to solve other problems.

Key words. Problem, universal machine, production, agricultural machines, tractor, experimental studies, transmission.

However, the need to create universal machine methods for solving technical standardization problems, applicable both for tractors and agricultural machines in operation and for their designed models, and also taking into account the all-mode nature of the tractor engine speed control, required further improvement of calculation methods. The basis of the proposed method Calculation of fuel consumption and speed of movement of the MTA is based on the results of analysis of data from traction tests of tractors and bench tests of engines, as well as the results of field experimental studies of MTA under various load and speed conditions of tractor operation

The technical characteristics of the tractor provide the values of the nominal traction forces Pcr n and the design speeds Vtr without taking into account the slip coefficient of the road wheels for each transmission gear. To determine the actual speed of movement of the power vehicle Vt, it is necessary to know the slip coefficient δ and the degree of speed reduction depending on the traction force Pcr ,

In accordance with GOST 24056-2010. “Methods for operational and technological assessment of machines at the design stage”, the coefficient δ is recommended to be expressed as a function of the ratio of the traction force Pcr to the adhesion weight of the tractor Gsc. As a result of processing data from traction tests of tractors, it was found that with an increase in Pcr/Gsc the value of δ increases according to a quadratic dependence (Fig. 1), while the dispersion of data for tractors of the same design is 1...3%, which is quite acceptable for practical calculations.

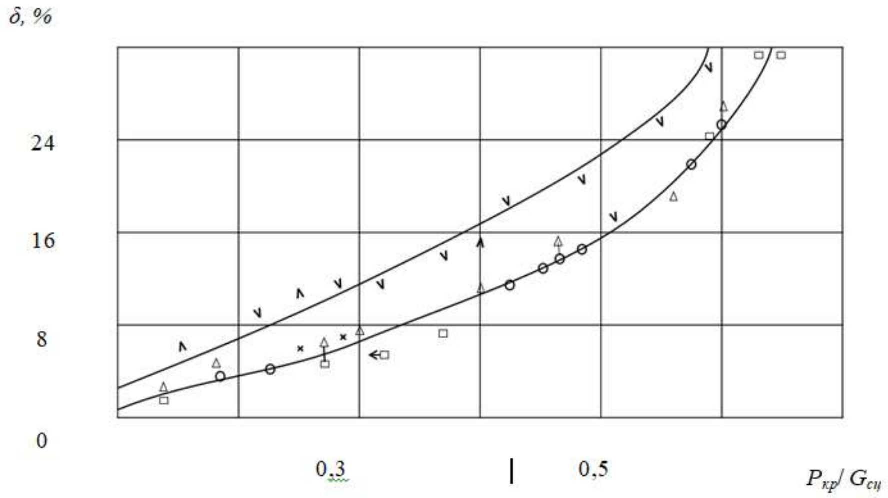


Fig. 1. Dependence of the slip coefficient on the ratio Pкр on the stubble of cereal grains: □, o, ▲, ● v ^ - data corresponding to tractors K-710M, K-700, K-701, T-150K, MTZ-80, MTZ- 82, TTZ-80-11

With the same values of the ratio Pcr/Gsc, the value of the coefficient δ of the MTZ-80 tractors is slightly higher than that of the T-150K and K-700 tractors. This indicates better utilization of the traction weight of tractors with an articulated frame compared to tractors with steered front wheels, having the 4x4 and 4x2 wheel formulas, respectively. [8]
To describe the dependence δ=f(Pкр/Gcc) we use a simplified version of the empirical equation (4):

$$\delta = \alpha \frac{P_{\text{кр}}}{G_{\text{сц}}} + \beta \left(\frac{P_{\text{кр}}}{G_{\text{сц}}}\right)^2 \qquad (1)$$

The average values of coefficients α and β obtained when processing data from traction tests of tractors of the main brands are given in Table 1.

Empirical coefficients

Table 1

Type of agricultural background	**Coefficient**	**K-700 K-701**	**T-150K**	**TTZ-80-11**	**T-150**	**BT-150**
Stubble of cereal grains and annual grasses	α	-26,0	-4,2	3,5	-5,1	0,77
After harvesting corn	β	126,8	79,9	68,3	16,8	19,2
Field prepared	α	-17,0	-12,2	10,3	-7,6	-1,9
under the soil, freshly plowed field	β	128,2	142,8	75,9	394	293

Taking into account the above, we determine the speed of the tractor by the expression:

$$V_{\text{т}} = V_{\text{тр}}(1 - \delta) \qquad (2)$$

As you know, at each transmission gear, the speed of the energy vehicle increases with decreasing traction load, reaching a maximum at idle (Pcr = 0). Analysis of tractor traction test data shows that the speed increase coefficient.

$$\xi_4 = \frac{V_{т}}{V_{тм}}$$

$V_{т}$- speed at maximum traction power), characterizing the intensity of the speed change depending on the traction force and depending on the degree of unevenness of the engine shaft speed control and slipping of the tractor propulsion, for wheeled tractors it is on average 1.16...1.25, for tracked ones - 1.10...1.14 (Table 2)

Odds value ξ_v are quite close in value for the entire range of transmission gears of the indicated types of tractors and can be applicable for promising models of energy vehicles. [9] Considering that dependence $V_{т} = f \cdot P_{кр}$ can be more accurately described by a quadratic dependence; generalized dependences of speed on traction force in dimensionless coordinates were obtained $\frac{P_{кр}^2}{P_{кр}^2 U} - \frac{V_{т}}{V_{тм}}$ - the ratio of current values to nominal values (Figure 2). To determine the current values of the coefficients ξi at $0 < P_{кр} < P_{крн}$ depending on the $\frac{P_{кр}^2}{P_{крн}^2}$ We use the linear interpolation method.

Odds value

Table 2

Type of agricultural background	**К-700, К-701, Т-150К**	**TTZ-80-11, MTZ-80/82**	**BT-150**
Fallow land, planets of perennial grasses, strong compacted stubble	1,160	1,22	1,10
Stubble of grain strips and annual grasses, field after corn harvesting	1,170	1,23	1,11
Steam, field after harvesting root crops, after plowing	1,175	1,24	1,12
Field prepared for sowing, freshly plowed field	1,185	1,25	1,14

The values of the coefficients ξv obtained experimentally and calculated using equation (3) are in good agreement, the difference between them does not exceed 4.5%, which indicates the possibility of using this method for describing speed for practical calculations, using only the nominal technical indicators Pcr and K_tr. When V=f·Pcr dependence is described by linear functions, the deviations of the calculated speed values from the actual ones reach 15%.

Given the expression $\xi = \frac{V_{Ti}}{К_{тн}}$ equation (3) will take the form:

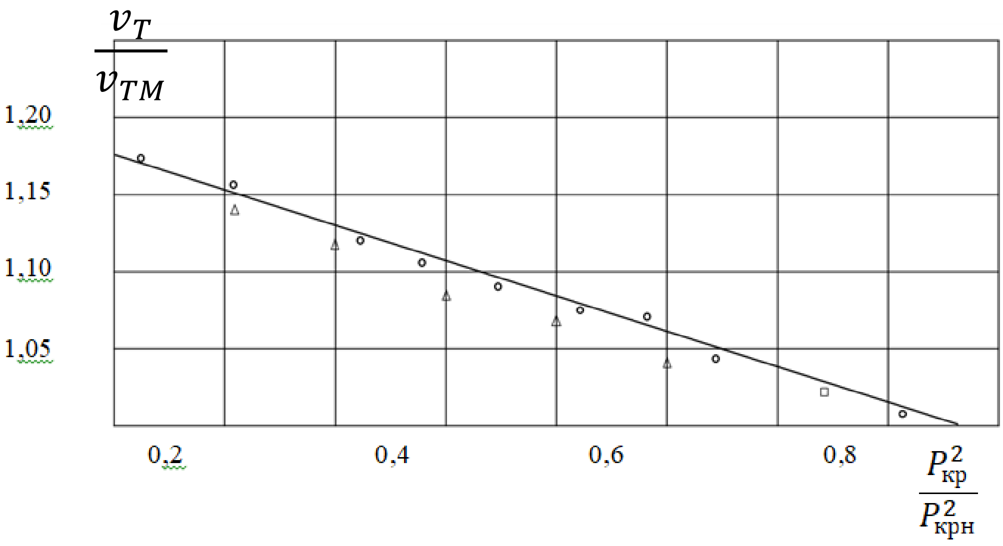
$$V_{Ti} = V_{ТМ}\left[\xi_v + (1-\xi_v)\frac{P_{кр}^2}{P_{рн}^2}\right]$$

The traction resistance of the unit Pc is equal in a steady state, equal to the movement in a steady state

Let us represent the traction force of the tractor Pcr by the well-known expression:

$$P_c = K_c\left[1 + \alpha_0\left(V_p + V_0\right)\right]\text{В}_\text{р}$$

Where Pc is the specific resistance of the machine-implement at speed;
α_0-coefficient taking into account the effect of speed on resistivity;
Br is the working width of the machine tools



Picture. 2. Generalized dependence of speed on traction - effort in dimensionless coordinates for the T-150K tractor when operating on grain stubble: □, o, ▲, ● - respectively, transmission gears 1....4

To coordinate the energy capabilities of the tractor and agricultural machine, the mode is combined with equations (4) and (5) regarding VP and PC, keeping in mind that in absolute value $P_C = P_{KP}$, and V + C = Vp. Let us present the system of equations in the following form;

$$V_p = V_{\text{тм}} \cdot \xi_v + (1 - \xi_v) V_{\text{тм}} \cdot \frac{P^2_{\text{кр}}}{P^2_{\text{кр н}}}$$

$$R_c = R_0 \cdot B_p + R_0 \cdot \alpha_0 \cdot B_p V_p - R \cdot \alpha_0 \cdot B_p \cdot V_0$$

$$A \cdot R_c^2 + B - V_p = 0$$

$$C \cdot V_p + D - R_c = 0$$

$$A = \frac{1 - \xi_v}{P^2_{\text{кр н}}} \cdot V_{\text{тм}}$$

$$B = V_{\text{тм}} \cdot \xi_v$$

$$C = R \cdot \alpha_0 \cdot B_p$$

The value of coefficient D for traction and traction-drive units was calculated accordingly using the following formula:

$$D = R \cdot B_p (1 - \alpha_0 V_c)$$

$$D = R \cdot B_p (1 - \alpha_0 V_c) + (G_M + G_T) \cdot f_M \cdot g \frac{3{,}6(N_X + N_P)}{V_{\text{тм}} \cdot \eta_{\text{вом}}} \qquad 6)$$

Where: G_M,G_T - mass of the machine and technological load;
f_M - coefficient of resistance to rolling of the machine;
g - acceleration of free putting on;

N_X - power consumed through the PTO for the idle drive of the working bodies;
N_P=Ny·gf - power consumed through the PTO to perform the technological process;
Ny - specific power per unit of material supplied to the machine;
gf - transmission supply of the energy vehicle (at main work - 0.8....0.9, at turns and crossings - 0.6....0.7);
η_{vom} - efficiency of the PTO mechanism (0.95 ....0.96).

After solving the system of equation (7) we obtained the following dependencies:

$$R_c = \frac{1-\sqrt{1-4AC(CB+D)}}{2AC}$$

$$V_p = B + \frac{1-\sqrt{1-4AC(CB-D)}}{2AC}$$

It is known that in the correction-free section of the regulatory characteristics of a tractor engine, the dependences of hourly fuel consumption on the engine load factor are identical for different brands of power plants (3) and can be represented by the equation: [10]

$$G_T = g_{\text{ен}} \cdot N_{\text{e}} \left(\frac{a}{\xi x_{\text{e}}} + b \right)$$

Where: g_en - specific fuel consumption at rated engine power N_en;
N_e - current value of engine power;
a,b - empirical coefficients;

Empirical coefficients characterize, respectively, the share of fuel energy consumption to overcome mechanical losses in the engine and the angle of inclination of the line, G_T=f(N_e)кN_e which is depicted on a graph with dimensionless coordinates (Fig. 3). The construction of this dependence for different values of the coefficient Tc for reducing the speed mode of the SMD-62 engine of the T-150K tractor shows (Fig. 4) that the nature of its passage is identical both for γ=1 and for γ<1. For tractor engines MTZ-80 and K-701, the nature of this dependence is similar. [11]

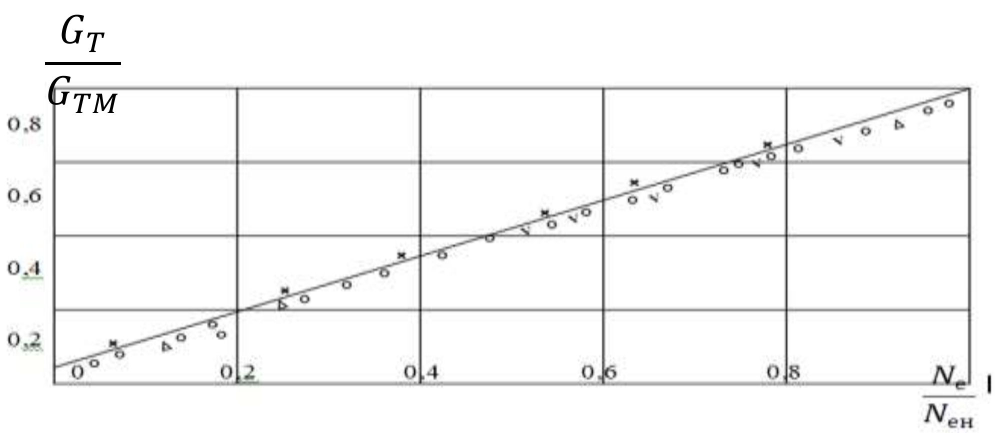


Fig.3. Dependence of the degree of utilization of fuel consumption on the engine load factor at values equal to
I(0), C MD-62X-γ n3-240BA-A1401, □-SMD-60 V-D-244

Based on the results of statistical processing of data from bench tests of diesel engines (Table 3), it was established that for the regulatory section of the characteristic, coefficients a and b have the following average values: 0.25 and 0.75.

Table 3

Numerical values of coefficients and

Engine make	Hourly fuel consumption, G_T kg		a	b
	At maximum power	At idle power		
D-21	4,0	1,1	0,27	0,73
D-21A	4,75	1,35	0,28	0,72
D-21E	9,25	2,8	0,30	0,70
D-30	10,8	3,1	0,29	0,71
D-240	14,8	3,75	0,23	0,75
AM-41	16,65	4,5	0,27	0,73
AM-01	24,0	6,0	0,25	0,75
SDM-60	27,7	6,0	0,22	0,78
SDM-62	30,5	7,5	0,24	0,76
YMZ-238NB	38,5	10,0	0,26	0,74
YMZ-240B	55,0	15,5	0,28	0,72
YMZ-240N	89,7	22,1	0,24	0,76

The dependence of the hourly fuel consumption G_T on the traction force of the tractor P_{cr} is almost linear in nature and for its analytical description it is necessary to have the values of the hourly fuel consumption at maximum traction power G_{TM} and at idle power of the tractor G_{TX}. [12]

If the value of G_{TM} can be determined quite accurately by calculation, determining G_{TXx} by calculation is difficult due to the fact that the traction efficiency of the tractor and the specific effective fuel consumption of the engine, necessary for calculating G_{TXx}, are set and regulated only for the nominal traction force $P_{(cr\ n)}$ and the rated power N_{en} power plant. Therefore, instead of defining, we will find on the graph of the traction characteristics of the tractor the coordinates of the point corresponding to the resistance to movement reduced to the engine shaft and the losses in the transmission of the energy vehicle P_{fn}, which corresponds to the fuel consumption spent on idling the engine G_{TX}.

The reduced resistance was determined by the formula:

$$P_{fn} = \frac{G_{\text{тр}} \cdot g \cdot f_{\text{т}}}{10^3 \cdot \eta_{\text{мг}}}$$

Where: G_{tr} - tractor weight, kg;

f_t - coefficient of resistance to rolling of the tractor.

Fuel consumption when the engine is idling is:

$$G_{TX} = Q \cdot G_{\text{тн}} = 0{,}25 G_{\text{тн}}$$

Taking into account the above and the dependence of hourly fuel consumption on traction force P_{cr}=R_c, which is based on the rules of linear interpolation, the following equations can be written:

$$G_T = 0{,}25 \cdot h_{\text{тн}} + \left(P_{fn} + P_{kpi}\right) \frac{G_{tmi} - 0{,}25 G_{\text{тн}}}{P_{fn} + P_{kpm}}$$

In the process of determining the speed of movement V_p and the hourly fuel consumption G_T, the condition $P_{cr}=R_c=0.92P_{crn}$ must be met in the selected gear of the tractor transmission. If this condition is not met, the calculation is carried out for a lower gear. In turn, the speed of movement of the MTA should not exceed the speed V_{pq} permissible according to agrotechnical requirements for a given agricultural machine.

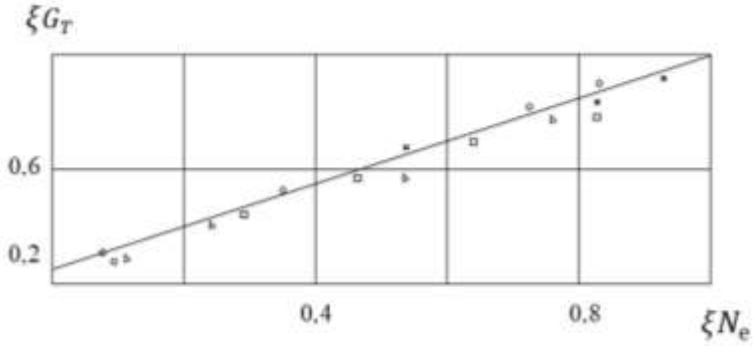


Fig.4. Dependence of the degree of utilization of fuel consumption ξG_T on the engine load factor ξNe at values of γc equal to 1(0), 0.9(l), 0.85(▲) and 0.6(□)

When the operating speed of the MTA is limited and the tractor is underloaded ($Rc \ll 0.92Pcr$), to increase the fuel efficiency of the engine, its partial operating modes should be used, i.e. it is necessary to engage higher gears and reduce the engine shaft speed to maintain the speed Vp=Vpq. The transmission gear that can be switched to without overloading the engine is established by comparing the traction resistance, approximately found by formula (5), with the nominal traction force of the tractor Pcrn for a number of gears. After this, for the selected tractor gear, the operating speed Vp, traction resistance Rc and hourly fuel consumption Gt are determined using the method described above, when the engine is operating at the nominal speed mode.
In partial engine operating modes, fuel consumption depends on the engine shaft speed, which is related to the tractor speed by the following ratio:

$$n_g = n_{g\text{н}} = \frac{V_{Ti}(1-\delta_\text{н})}{V_{TM}(1-\delta_\text{т})}$$

Where: δn, δт - slip coefficients of tractor propulsors at nominal and actual traction forces.
As a characteristic of the engine speed mode, we used the speed reduction coefficient γc, which represents the ratio of the engine shaft rotation speed at idle when operating in intermediate and nominal modes. Modern tractor engines operate stably with changes in γc within the range of 1.0....0.6. The lower limit γc ensures the stability of the functioning of the main systems of the engine and tractor.
The engine shaft rotation speed at idle when the engine is running at partial speed, corresponding to the speed of the MTA in this mode, is unknown. Therefore, we determined not the actual, but the approximate value of the coefficient γc, equal to the ratio of the engine shaft rotation speed at the speed allowed by agrotechnical requirements and at the speed obtained by calculation. The obtained value of γc differs from the actual value by no more than 3....4.2, which is acceptable for practical calculations. [13]
Based on the value of γc, it is possible to determine the possible fuel economy ΔGt (Fig. 5) when using partial engine operating modes and, taking into account the previously found value of fuel consumption, calculate the actual fuel consumption:

$$G_{т\Delta} = G_{т}\left(\frac{\Delta G_{т}}{100}\right)$$

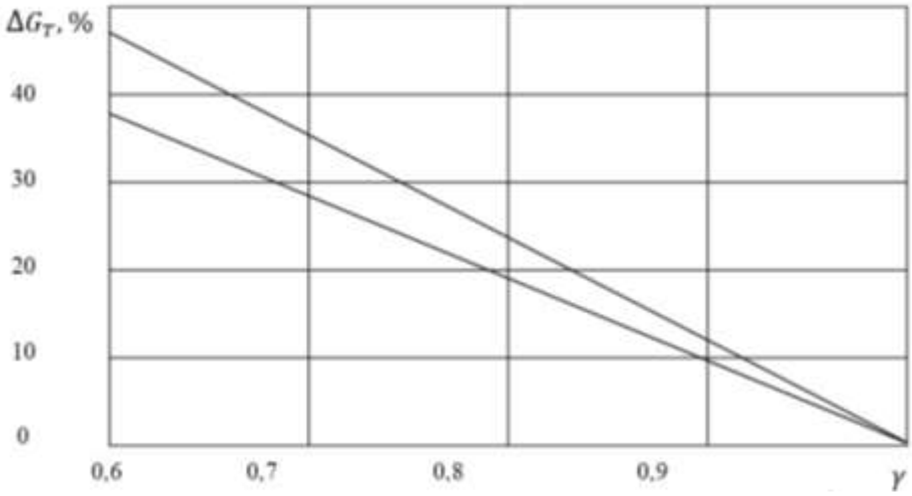


Fig.5. Generalization of the dependence of hourly fuel consumption savings ΔGt MTA on the engine speed reduction coefficient γs

The use of the proposed method makes it possible to establish fuel consumption standards for new equipment being introduced, and also increases the degree of their accuracy when performing MTA low-energy-intensive work.

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