METHODS FOR SELECTION OF THE ENGINES OF AGRICULTURAL TRACTORS ACCORDING TO FUEL ECONOMY

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Methods for selection of the engines of agricultural tractors, in order to insurance of the minimum fuel consumption, is suggested. The essence of methods reduces to selection of the engine power as be based on the requirement for the most likely working regimes the engine to work at regime near to minimum specific fuel consumption. Concrete data, for determination and selection of the fundamental tractor parameters, are given in this paper, with which to be able the methods apply at design and research of exploitation properties of the tractors.

Keywords: agricultural tractors, minimum fuel consumption.

1. Introduction

The selection of the engine of agricultural tractors is made according to methods, reading the optimal (nominal) values of the tractive force F_{T0} of the real rate of movement V_0 and for optimal values of the tractive efficiency coefficient η_{TO} at work on stubble [1,2,3,4]. The nominal engine power for these conditions is determinate by relation

$$P_H = \frac{F_{T0} V_0}{\eta_{T0}} k, \tag{1}$$

where k is coefficient, increase the engine power, with purpose of to guarantee its indexes in exploitation, k = 1,15÷1,20; P_H - nominal engine power.

This methods, for selection of the engine, create following main problems [5,6,7,8,9]:

- usually at accomplishing of the main agricultural operations, it is recommended the engine to work on external regulating branch. With this it is ensured determinate rate of movement, because of the rotation frequency of the engine is varied insignificantly on the regulating branch. For these conditions the engine torque and the tractive resistance are varied in large boundaries, and the specific fuel consumption is significantly bigger than its minimum (fig.1);
- at heavy (basic) kinds of work the engine works at regime near to nominal,

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that leads to decrease of its resource. Besides, of work at regime about nominal, the engine has hour fuel consumption, which is with about 20% bigger than this at regime $g_{e\,min}$ (M_G - ω_G, fig.1).

With the purpose of decrease the fuel consumption for unit accomplishing work and of the hour fuel consumption, after 1980 it is recommended that the engine to work at partial regimes, with this it is achieved working regime with smaller specific fuel consumption g_e [5,8,9]. Essentially, that is mean, that the regime of the engine and number of switched gear, and the regimes of working machines to regulate and/or to select in exploitation conditions thus, that the torque and the rotation frequency of the crankshaft to be near to point M_G - ω_G (fig.1).

Reading this, the object of this work is to suggest methods for selection of the engine thus, that for main kinds of work the engine to work about point M_G - g_{emin} (fig.1).

2. The essence of methods

The essence of methods is, that for main working regimes, characterizing with optimal values of the tractive force F_{T0} and of the real rate of movement V_0 the engine to work in point M_G - $g_{e\,min}$ (fig.1) [5,9].

a) Determination of the necessary engine power P_G (fig.1).

Of possibility the engine to work in / about point M_G - g_{emin} the engine power P_G necessary for overcom of the tractive resistance F_{T0} at rate of movement V_0 may determinate according to relation

$$P_G = \frac{F_{T0}\,V_0}{\eta_{T0}} \;, \tag{2}$$

where P_G is engine power for overcoming of the tractive resistance F_{T0} at rate V_0 realized at regime in point M_G - $g_{e\,min}$ (fig.1).

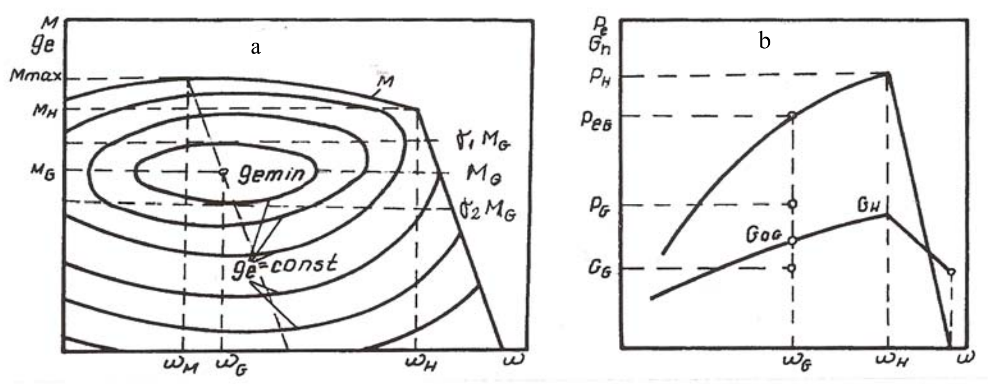

Fig.1. Characteristics of the diesel engine with each regime regulator : a) universal economy characteristic; b) external regulator characteristic

From the relation (2) it is seen, that for engine selection it is necessary to determinate the value of the tractive efficiency coefficient for the respective load and working regime of the tractor and its aggregates. Besides, the transmissions ratios must select as, that for given conditions the engine to work at/about point M_G - g_{emin} .

b) Optimal value of the efficiency coefficient η_{T0}.

The value of η_{T0} in relation (2) may determinate from the extremity of function η_{T0} - T , expressed with relation [1,3,4]

$$\eta_T = \eta_\delta \, \eta_f \, \eta_{MG} \, , \tag{3}$$

where each efficiency coefficient - of the slippage η_δ, of the moving resistance η_f and of the mechanical efficiency coefficient of the transmission η_{MG} may calculate by respective relation

$$\eta_\delta = 1 - A \ln \frac{B}{C-T}, \quad \eta_f = \frac{\lambda_K T}{T\lambda_K + f}, \quad \eta_{MG} = \eta_c^c \eta_k^k \left(1 - \frac{\xi}{\gamma_{MG}} \right), \tag{4}$$

where A, B and C are coefficients in empiric relation $\delta = f(T)$;

T - tractive factor, $T = F_T / G_k$;

G_k - cohesion weight, kN; λ_k - load coefficient of the driving axle - $\lambda_K = \dfrac{G_K}{G_0}$; η_c - efficiency coefficient of one couple cylindrical wheels of the transmission;

c - number of couples cylindrical wheels (poles), with which the transmission of the power flow from engine to wheel, is accomplished;

η_k - efficiency coefficient of one couple conical wheels;

κ - number of couples conical wheels (poles), with which the transmission of the power flow is accomplished;

ξ - coefficient, reading the idle running losses in packing and for oil spilling over transmission;

γ_{MG} - coefficient of engine load at work in point M_G - ω_G ;

f – coefficient of moving resistance.

Reading (3) and (4) for total tractive efficiency coefficient of the tractor is received

$$\eta_T = \eta_c^c \eta_k^k \left(1 - \frac{\zeta}{\gamma_{MG}} \right) \left(1 - A \ln \frac{B}{C-T} \right) \left(\frac{\lambda_K T}{\lambda_K T + f} \right), \tag{5}$$

The determination of the optimal value of the tractive efficiency coefficient η_{T0} is accomplished with determination of the extremity of the function or with determination of the multipliers in (5) separately.

-the mechanical efficiency coefficient η_{MG} at work of the engine in point P_G (M_G - ω_G) by reading of the load stage according to torque;

-maximum value of the function $\eta_\delta \eta_f = \eta_{f\delta}$.

The determination of the coefficient γ_{MG} is accomplished according to fig.1 by the relation

$$\gamma_{MG} = \frac{M_G}{M_H} \quad . \tag{6}$$

If the numerator and the denominator multiply with $\omega_G \omega_M$ and with respectively transformation, for γ_{MG} is received

$$\gamma_{MG} = \frac{M_G}{M_H}\,\frac{\omega_G\,\omega_H}{\omega_G\,\omega_H} = \frac{P_G}{P_H}\,\frac{\omega_H}{\omega_G} = U_{p1}.U_{p2}/U_\omega, \tag{7}$$

where U_ω, U_{p1}, U_{p2} are coefficients, characterizing the main indexes of the engine $U_\omega = \omega_G / \omega_H$; $U_{P1} = P_G / P_{eG}$; $U_{P2} = P_{eG} / P_H$, shown on fig.1.

For subsisting diesel engines with each regime regulator in this stage may accept $U_\omega = 0{,}75$; $U_{P1} = 0{,}75$; $U_{P2} = 0{,}74$ [1,2].

After replacement of (7) in (4) for η_{MG} finally is received

$$\eta_{MG} = \eta_c^C \eta_K^k \left(1 - \xi \frac{U_\omega}{U_{P1} U_{P2}} \right), \tag{8}$$

The maximum value of the coefficient $\eta_{f\delta}$ is received by investigation of the function $\eta_f \eta_\delta = f(T)$ and it is determinate by graph relations of the kind, shown on fig.2 or take by the tabl.1 [6].

b) The maximum (nominal) engine power may determinate comparatively quickly, if there is universal economy characteristic of the engine (fig.1a). Very often, there are not such characteristics, besides it is used average statistic data (graph or empiric) for the coefficients U_{P2} and U_ω .

Table.1

Indexes	Type of the tractor	Asphalt	Dirt road	Stubble	Cultivating field
$\eta_{f\delta(max)}$ (η_{MG}=0,87)	Wheel 4к2	0,92	0,85	0,64	0,46
	Wheel 4к4 ($r_1<r_2$)	0,91	0,84	0,67	0,52
	Wheel 4к4 ($r_1=r_2$)	0,92	0,84	0,68	0,54
T_O	Wheel 4к2	0,45	0,45	0,4	0,33
	Wheel 4к4 ($r_1<r_2$)	0,375	0,36	0,35	0,30
	Wheel 4к4 ($r_1=r_2$)	0,40	0,37	0,36	0,32
δ_O	Wheel 4к2	0,05	0,085	0,16	0,21
	Wheel 4к4 ($r_1<r_2$)	0,04	0,07	0,14	0,20
	Wheel 4к4 ($r_1=r_2$)	0,035	0,07	0,12	0,19

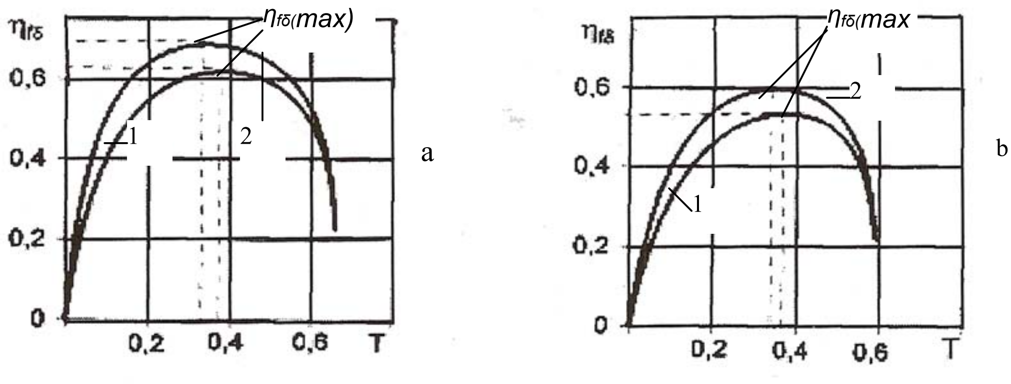

Fig.2 Characteristic of the product $\eta_f\eta_\delta = \eta_{f\delta}$ for determination of the optimal tractive factor T_0 for tractor 4X2 a) for stubble, b) for cultivating field (1,2 – boundaries of alteration).

After the values of these coefficients are selected, the nominal engine power may calculate by the relation

$$P_H = \frac{P_G}{U_{p1}U_{p2}}. \tag{9}$$

The connection, between the nominal engine power and current value of the power of arbitrary point of the external characteristic, may express by known relations of the literature [1]

$$P_H = P_{eG}\left[a\left(\frac{\omega_G}{\omega_H}\right) + b\left(\frac{\omega_G}{\omega_H}\right)^2 + c\left(\frac{\omega_G}{\omega_H}\right)^3 + d\left(\frac{\omega_G}{\omega_H}\right)^4\right] \tag{10}$$

By the fig.3b the value of U_ω for minimum value of k_ω, is determinate, after that reading

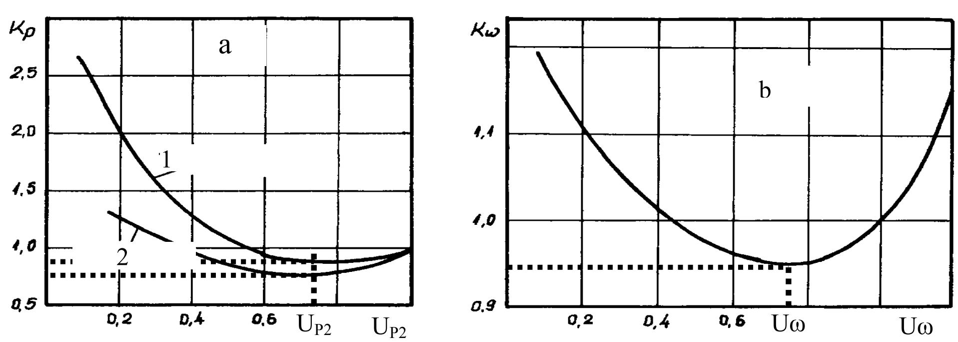

Fig.3. Average graph relations for determination of the specific fuel consumption g_e, expressed the connection between P_{eG}, P_H and ω_G/ω_H; 1- benzene , 2- diesel.

relation ω_G/ω_H by the figure is replaced in (8) and the coefficient U_{P1}.is calculated.

c) Determination the transmission ratio of the gear i_{TG}.

The transmission ratio i_{TG} of the gear, ensuring work of the engine with tractive load
F_{T0} and rate of movement V_0 at work of the engine in point M_G - ω_G may determinate by following relation

$$i_{TG} = \omega_G r_k / (V_0(1-\delta_o)), \quad (11)$$

where r_k is kinematics radius of rolling of the driving wheels of the tractor;

δ_0 – slippage of the tractor at tractive force F_{T0}.

In this stage remained transmission ratios of the gear may determinate by one of known in the literature methods. In the future methods, allowing and for remaining regimes of work to reach engine work about point M_G - ω_G , to search for.

4. Conclusions

1. Methods for engine selection of the agricultural tractors, with the purpose of ensure decrease of the fuel consumption for unit accomplished work, are suggested.
2. In this stage the using of these methods is possible as the suggested approaches are used for determination of the basic parameters, taking part in the relations for calculation of the necessary and of the nominal engine power.
3. It is necessary the investigations, connected with selection of the basic parameters at calculation of the power, to be extended with the purpose of the their optimization.

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