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

Nedka STANCHEVA, M.MARINOV, D. STANCHEV

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 $\eta_{T0}$ at work on stubble [1,2,3,4]. The nominal engine power for these conditions is determinate by relation

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

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 $g_{e_{\text{min}}}(M_G - \omega_G$, 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 $M_G - \omega_G$ (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 $M_G - g_{e_{\text{min}}}$ (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 $M_G - g_{e_{\text{min}}}$ (fig.1) [5,9].

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

Of possibility the engine to work in / about point $M_G - g_{e_{\text{min}}}$ 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

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

(2)

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

Fig.1. Characteristics of the diesel engine with each regime regulator : a) universal economy characteristic; b) external regulator characteristic
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From the relation (2) it is seen, that for engine selection it is necessary to determine 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 $M_G - \xi_{\min}$.

**b) Optimal value of the efficiency coefficient $\eta_{T0}$.**

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

$$\eta_T = \eta_\delta \eta_f \eta_{MG} .$$

(3)

where each efficiency coefficient - of the slippage $\eta_\delta$ of the moving resistance $\eta_f$ and of the mechanical efficiency coefficient of the transmission $\eta_{MG}$ may calculate by respective relation

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

(4)

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

- T - tractive factor, $T = FT / G_k$;
- $G_k$ - cohesion weight, kN;
- $\lambda_k$ - load coefficient of the driving axle - $\lambda_K = G_K / G_0$;
- $\eta_c$ - 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;

- $\eta_k$ - efficiency coefficient of one couple conical wheels;
- $\kappa$ - number of couples conical wheels (poles), with which the transmission of the power flow is accomplished;
- $\xi$ - coefficient, reading the idle running losses in packing and for oil spilling over transmission;

- $\gamma_{MG}$ - coefficient of engine load at work in point $M_G - \omega_G$;
- $f$ - coefficient of moving resistance.

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

$$\eta_T = \eta_c \eta_k \left( 1 - \frac{\xi}{\gamma_{MG}} \right) \left( 1 - A \ln \frac{B}{C - T} \right) \left( \frac{\lambda_K T}{\lambda_K T + f} \right) ,$$

(5)

The determination of the optimal value of the tractive efficiency coefficient $\eta_{T0}$ is accomplished with determination of the extremity of the function or with determination of the multipliers in (5) separately.
- the mechanical efficiency coefficient $\eta_{MG}$ at work of the engine in point $P_G$ ($M_G - \omega_G$) by reading of the load stage according to torque;
- maximum value of the function $\eta f \eta_f = \eta_f$.

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

$$\gamma_{MG} = \frac{M_G}{M_H}.$$  \hspace{1cm} (6)

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

$$\gamma_{MG} = \frac{M_G}{M_H} \frac{\omega_G \omega_H}{\omega_G \omega_H} = \frac{P_G}{P_H} \frac{\omega_H}{\omega_G} = \frac{U_{p1}}{U_{p2}} / \omega_H,$$  \hspace{1cm} (7)

where $U_{\omega}, U_{p1}, U_{p2}$ are coefficients, characterizing the main indexes of the engine $U_{\omega} = \omega_G / \omega_H$; $U_{p1} = P_G / \omega_G$; $U_{p2} = P_{\omega} / \omega_H$, 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 $\eta_{MG}$ finally is received

$$\eta_{MG} = \eta_c \eta_k \left( 1 - \xi \frac{U_{\omega}}{U_{p1} U_{p2}} \right).$$  \hspace{1cm} (8)

The maximum value of the coefficient $\eta_f$ is received by investigation of the function $\eta_f = f(T)$ 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 $U_{\omega}$.

<table>
<thead>
<tr>
<th>Indexes</th>
<th>Type of the tractor</th>
<th>Asphalt</th>
<th>Dirt road</th>
<th>Stubble</th>
<th>Cultivating field</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta_{f(\text{max})}$ $\eta_{MG}=0,87$</td>
<td>Wheel 4k2</td>
<td>0,92</td>
<td>0,85</td>
<td>0,64</td>
<td>0,46</td>
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<tr>
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<td>Wheel 4k4 ($r_1 &lt; r_2$)</td>
<td>0,91</td>
<td>0,84</td>
<td>0,67</td>
<td>0,52</td>
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<tr>
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<td>Wheel 4k4 ($r_1 = r_2$)</td>
<td>0,92</td>
<td>0,84</td>
<td>0,68</td>
<td>0,54</td>
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<tr>
<td>$T_o$</td>
<td>Wheel 4k2</td>
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<tr>
<td>$T_o$</td>
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<tr>
<td>$\delta_o$</td>
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<td>0,085</td>
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<tr>
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<td>0,07</td>
<td>0,14</td>
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<tr>
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<td>0,035</td>
<td>0,07</td>
<td>0,12</td>
<td>0,19</td>
</tr>
</tbody>
</table>
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After the values of these coefficients are selected, the nominal engine power may calculate by the relation

$$P_H = \frac{P_G}{U_{p1}U_{p2}}.$$  \hspace{1cm} (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]

$$P_H = P_{eG} \left[ a \left( \frac{\omega_G}{\omega_H} \right) + b \left( \frac{\omega_G}{\omega_H} \right)^2 + c \left( \frac{\omega_G}{\omega_H} \right)^3 + d \left( \frac{\omega_G}{\omega_H} \right)^4 \right].$$ \hspace{1cm} (10)

By the fig.3b the value of $U_{\omega}$ for minimum value of $k_{\omega}$, is determinate, after that reading

Fig.2 Characteristic of the product $\eta_f \eta_b = \eta_{f0}$ for determination of the optimal tractive factor $T_0$ for tractor 4X2 a) for stubble, b) for cultivating field (1,2 – boundaries of alteration).

Fig.3. Average graph relations for determination of the specific fuel consumption $g_{e\omega}$, expressed the connection between $P_{e\omega}$, $P_H$ and $\omega_G/\omega_H$; 1- benzene, 2- diesel.
relation $\omega_G/\omega_H$ 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 $M_G - \omega_G$ may determine by following relation

$$i_{TG} = \frac{\omega_G r_k}{V_0(1-\delta_o)} \tag{11}$$

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

$\delta_o$ – 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 $M_G - \omega_G$, 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.

REFERENCES