INTERMEDIATE REGULARITIES ON THE ENERGETICAL PARAMETERS OF THE TRACTOR ENGINES

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Abstract. The efficiency of tractors applied in agriculture is usually estimated as an integrated value including the indices of their intensive and extensive utilisation. The application intensity of tractors and machines is characterized by their working capacity per unit of time An important factor in fuel consumption is the engine loading. The presented generalised curves of the diesel engine loads show in percentage the variations in the values of the indices characterising the operation of the engine: the total fuel consumption, the torsional moment (the moment of rotation), the number of crankshaft revolutions and the specific fuel consumption depending on the effective power developed by the engine (also in percentage). If the engine loading falls, the specific fuel consumption rises, at first, at a slower rate (up to about 80 % loading), but further it increases more and more rapidly. As a result of conducted theoretical investigations, carried out in the Research Institute of Agricultural Machinery at the Latvia University of Agriculture in years 2007-2008, the intermediate regularities of the energetical parameters of the tractor engines are determined. These regularities mathematicaly interface the energetical indices of the tractor disel engines. It follows from this that the ratio of the engine loading may be determined by measuring the fuel consumption in a corresponding moment of time, the data saved in the data logger, and their interpretation using an appropriate computer programme.

Key words: generalised load curves of diesel engines, regularities of parameters, analytical relationships, fuel consumption.

Introduction

The efficiency of tractors and machines applied in agriculture is usually estimated as an integrated value including the indices of their intensive and extensive utilisation [1-4]. Brian Witney in his text book has written that good machine maintenance and efficient operation can save a further 10 per cent of the annual fuel costs [5], but does not given any guidelines for its consummation.

The application intensity of tractors and machines is characterized by their working capacity [2, 4, 6-11], that may be characterised with fuel consumption per unit of time [12]. N. Kopik caried out investigations for controlling work of tractor aggregates from distance and was worked out equiment for its writing down [13]. However this device was not enaugh precise, because it showed medial values of fuel consumption in time period, but not momentanily, as well as it had not ability to determin others indices of tractors engine work.

Engine of some up to date tractors have ability to showe momentanily fuel consumption, but it not chracterise economical efficiency of the engine work [14].

An important factor in fuel consumption is the engine loading [6-11, 15, 16]. The presented curves of the diesel engine loads [17] show the variations in the values of the indices characterising the operation of the engine: the total fuel consumption, the torsional moment (the moment of rotation), the number of crankshaft revolutions and the specific fuel consumption depending on the effective power developed by the engine. On its basis are created generalised curves of the diesel engines for tractors applicaded previous in the USSR [2, 15]. However, there are not enough correlations among indices of engine functioning.

The purpose of this study is, by applying the methods of mathematical approximation, to determine intermediate regularities of the energetic parameters of tractor diesel engines that provide to join together the main parameters of the tractor diesel engines and may be used to create a computer programme and an algorithm for the calculation of the values of the engine working parameters and assessment of efficient use of the tractors.

Materials and Methods

This article presents results of the theoretical investigations, carried out in the Research Institute of Agricultural Machinery at the Latvia University of Agriculture in years 2007-2008.

The application intensity of tractors and machines is characterized by their working capacity per unit of time. In order to estimate the application intensity of the tractor, its engine loading (fuel consumption per unit of time) should be measured and fixed in the data logger. For energetic assessment of tractor diesel engines their loading characteristics should be used [15, 17]. As a basis of this investigation, generalised load curves of these engines [1-3, 15] are applied. In order to determine the intermediate regularities of, the energetic parameters of tractor diesel engines methods of mathematical approximation, such as the method of least squares, are used.

Results and Discussion

The specific fuel consumption of correctly aggregated machines performing agricultural operations does not depend on the capacity of the tractor but on its economy, which is determined by the specific fuel consumption of the engine for the production of a unit of energy g_e, g·(kWh)$^{-1}$ and the coefficient of its employment for the useful work k_u [1, 15]. The latter coefficient k_u characterises which part of the energy produced by the engine is used up in the technological operations. The lower is the specific fuel consumption of the engine and higher the coefficient k_u of the useful work (for example, the draft coefficient), the more economic may be the work of the tractor. Therefore, in order to save fuel, the tractors with the most economic engines should be used.

An important factor of fuel consumption is the engine loading. Figure 1 presents generalised curves of the diesel engine loads that show the variations in the values of indices characterising the operation of the engine: the total fuel consumption G, the torsional moment (the moment of rotation) M, the number of crankshaft revolutions n and the specific fuel consumption g_e depending on the effective power N_e developed by the engine (also in percentage) [1, 15].

$$g_e = G\,N_e^{-1} \tag{1}$$

It is obvious from the picture that, if the engine loading falls, the specific fuel consumption rises, at first, at a slower rate (up to about 80 % loading), but further it increases more and more rapidly (Figure 1).

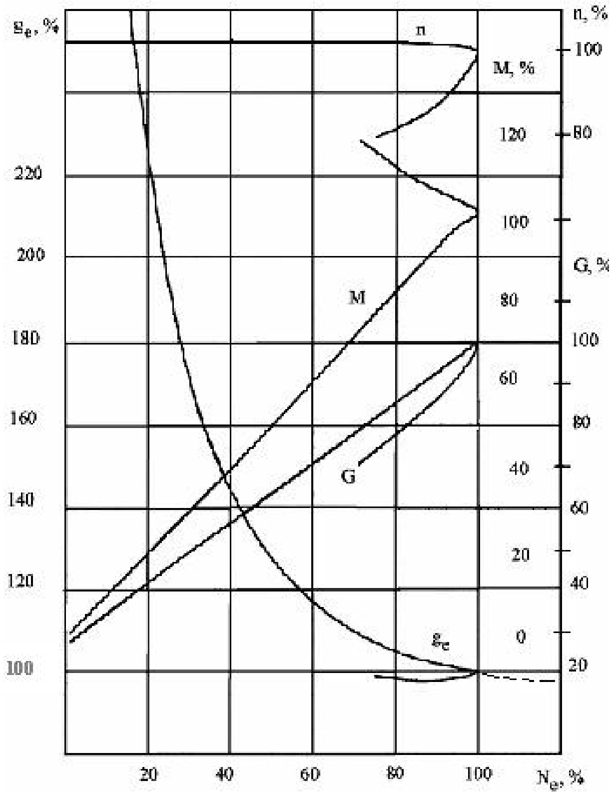

Fig. 1. **Generalised load curves of the tractor diesel engines:**
N_e – the efficient power, %; n – the rotational speed of the crankshaft, %; M – the moment of rotation, %; g_e – the specific fuel consumption related to a unit of work of the engine, %; G – the total fuel consumption per unit of time, %

It is evident from the graphs (Figure 1) that the total fuel consumption of the engine per unit of time G_i, also the specific fuel consumption g_e, are functions of the engine loading coefficient k_u:

$$G_i = f(k_{ui}) \; ; \tag{2}$$

$$g_e = f(k_{ui}) \; ; \tag{3}$$

$$k_{ui} = N_{ei} \cdot N_e^{-1} \tag{4}$$

Further, it follows from this correlation that the ratio of the engine loading k_{ui} may be determined by measuring the fuel consumption G_i in a corresponding moment of time, the data saved in the data logger, and their interpretation using an appropriate computer programme.

It is evident from the graphs (Figure 1) that the variation in the specific fuel consumption g_e depending on the effective power N_e has an alternative hyperbolic regress. The hyperbolical curve of g_e has two branches. Its upper branch is asymptotical to the vertical axis of coordinates. Its lower branch is asymptotical to the opinionative (imaginary) line g_{as}, that is parallel to the horizontal axis of coordinates at distance g_a. Following this interpretation, the equation of curve g_e may be written as the following formula:

$$g_{ei} = g_a \left(1 + g\, N_{ei}^{-1}\right) . \tag{5}$$

On its basis, by means of the method of least squares, the specific fuel consumption g_e, the distance to the horizontal asymptote g_a and specific modulator g are determined, using formulas:

$$g_a = \frac{\sum x^2 \sum y - \sum x \sum xy}{n \sum x^2 - \left(\sum x\right)^2} \tag{6}$$

$$g_a g = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - \left(\sum x\right)^2} \tag{7}$$

$$g = \frac{g_a g}{g_a} \tag{8}$$

where $x = N_{ei}^{-1}$;
$y = g_{ei}$;
n – the number of measurements (at least 5).

Using the above formulas, as an example, a calculation is carried out to determine the values of indices g_{ei}, g_a and g for the curve of the specific fuel consumption given in the graph above (see Tables 1 and 2)

Table 1

Data for the calculation of the values of indices characterising the curve of specific fuel consumption

The number of measurements	$N_{ei} = 1 \cdot x^{-1}$	$y = g_{ei}$	$x = N_e^{-1}$	xy	x^2
1	20	225	0.050	11.250	0.00250
2	30	175	0.033	5.775	0.00109
3	40	145	0.025	3.625	0.00063
4	50	130	0.020	2.600	0.00040
5	60	117	0.017	1.989	0.00029
6	70	110	0.014	1.540	0.00020
7	80	105	0.013	1.365	0.00017
8	90	102	0.011	1.122	0.00012
9	100	100	0.010	1.000	0.00010
$n = 9$	-	$\Sigma y = 1209$	$\Sigma x = 0.193$	$\Sigma xy = 30.27$	$\Sigma x^2 = 0.00550$

Table 2

Calculation of distance g_a between the horizontal asymptote and the axis of coordinate, and the value of modulator g

Distance g_a	65.64
$g_a\ g$	3178.9
Modulator g	48.73

Using the calculated values of indices for the curve characterising the specific fuel consumption, which is presented by the graph (Figure 1), formula (5) obtains the following concrete (particular) expression:

$$g_{ei} = 65.64\ (1 + 48.73\ N_e^{-1})\ . \tag{9}$$

It is evident from the graphs (Fig. 1) that the fuel consumption for efficient work of the engine per unit of time G_{ei} is proportional to the ratio (degree) of the engine loading N_{ei} (in %):

$$G_{ei} = (G_{100} - G_{nl})\ N_{ei}\ , \tag{10}$$

where G_{100} – the specific fuel consumption at a full (100 %) engine load;
G_{nl} – the fuel consumption of an unloaded (idle) engine.

The total fuel consumption G_i is the sum of its consumption by an unloaded engine (N_{ei}=0) and the efficiency of fuel consumption G_{ei} at the given load N_{ei}:

$$G_i = G_{nl} + G_{ei} = G_{nl} + (G_{100} - G_{nl})N_{ei}\ . \tag{11}$$

Further, it follows from the equation:

$$N_{ei} = G_i - G_{nl}\ (G_{100} - G_{nl})^{-1} \tag{12}$$

Irrespective of the concrete engine, the difference $G_{100} - G_{nl}$ has a constant value.

In a similar way, one can determine the moment of rotation M of the engine and its variations:

$$M_i = (M_{100} - M_{nl})N_{ei}; \tag{13}$$

$$M_i = (M_{100} - M_{nl})\ [G_i - G_{nl}\ (G_{100} - G_{nl})^{-1}]; \tag{14}$$

The obtained intermediate regularities functionally join together the main parameters of the tractor diesel engines. They allow to calculate for a known value of one parameter (for example, fuel consumption G_i) the values of other parameters (efficient power N_e , the degree of load k_{ui} , the specific fuel consumption g_e , the moment of the crankshaft rotation). The obtained intermediate regularities of the main parameters of the tractor diesel engines may be used to create a computer programme and an algorithm for the calculation of the values of the engine working parameters and assessment of efficient use of the tractor.

Based on results of this theoretical investigations tractor Mc CORMIC is equipped with computerised device for carrying out experimental trials in order to fix on its energetic indices and assess efficient of tractor use.

Conclusions

The obtained intermediate regularities of the main parameters of the tractor diesel engines allow calculate for a known value of one parameter the values of other parameters. They may be used to create a computer programme and an algorithm for the calculation of the values of the engine working parameters and assessment of efficient use of tractor.

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