OPTIMISATION OF PARAMETERS OF DIESEL'S REGULATOR AND LOADING

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During work engine-transmission system (ETS) of tractor continuously exposed to influence of casual loading rendering negative influence on its power and economic parameters. The reason of diesel characteristic's deviation from standard in field conditions are the infringements in formation of combustion mixture, nonlinearity of diesel characteristics and so on. Parameters of loading influencing work of diesel are frequency and amplitude. ETS during work acts as the filter of fluctuations. The fluctuations of drive wheel's rotation speed of various frequencies, coming on crankshaft of diesel, can amplify, be weakened or remain without changes. Besides parameters of loading, the important factors determining work of diesel, are the parameters of regulator: rigidity of spring and mass of weights. To specify ways of improvement of operational properties of tractors at casual loading, it is necessary to take into account influence of dynamic properties of engine on its power properties. For the decision of this task it is necessary to construct mathematical model of mobile agricultural unit. Now there are not mentioned questions devoted to complex research of power of diesel in space of four factors: rigidity of spring and mass of weights of regulator and frequency and amplitude of loading. The large interest is represented by optimisation of this parameters by results of researches.

A variety of works which are carried out by tractors and strict requirements dictate necessity of creation of tractors and units on their base capable to provide high quality with maximal productivity.

Important meaning have the power and economic characteristics of diesel engine and machine-tractor unit. They are: effective power of diesel, torque, rotation speed of diesel, charge of fuel, productivity of the tractor. Mobile units with parameters ensuring a high degree of capacity use of engine are necessary.

At an establishment estimation of target parameters of tractor the metod of function of casual arguments is applied. It's essence is, that tractor is considered as model "input – output" (Fig. 1).

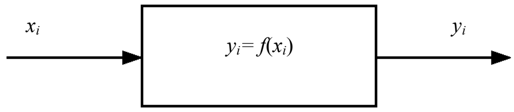

Fig. 1. Model "an input – exit": x_i – input value, y_i – output value, $y_i = f(x_i)$ – function of link

Input x_i and output y_i of variables are defined by the determined magnitude by a functional connection $y_i = f(x_i)$. As functions of link the functions obtained at approximation standard of performances of drives of tractors are applied.

The input value x_i represents an aleatory variable – rotational speed of a diesel engine.

The formula for definition $M\,(N_e)$ looks like:

$$M(N_e) = 9550^{-1}[0{,}5(a^*\overline{n}_D + b^*\overline{n}_D^2 + 0{,}5b^*A_n^2) - (a_1^*\overline{n}_D + b_1^*\overline{n}_D^2 + 0{,}5b_1^*A_n^2)\cdot \cdot F(z_H) + 0{,}5b_1^*A_n\beta(z_H)(3\overline{n}_D - n_H)]; \tag{1}$$

where:

$F\,(z_H) = \pi^{-1} - \arcsin\,(z_H)$,

$\beta(z_H) = \dfrac{\sqrt{1 - z_H^2}}{\pi}$ – functions of argument z_H, equal $z_H = (n_H - \overline{n}_D)\,/An$;

$An = \sqrt{2}\sigma_n$ – vibration amplitude of rotational speed,

σ_n – standard,

$a^* = A^*_1 + A^*_2$,

$a^*_1 = A^*_2 - A^*_1$,

$b^* = B^*_1 + B^*_2$,

$b^*_1 = B^*_2 - B^*_1$ – constants and coefficients, difiniendums on standard characteristic of diesel engine $M_K = f(n_D)$: $A_1^* = M_{max} + \ldots + [(M_H(K-1)n_{min}]/(n_H - n_{min})$; $A_2^* = M_H n_{XX}/(n_{XX} - n_H)$,

$B_1^* = -[M_H(K-1)]/(n_H - n_{min})$,

$B_2^* = -M_H/(n_{XX} - n_H)$ $K = M_{max}/M_H$ – coefficient of an adaptivity of diesel engine,

M_H – rated torque of a diesel engine,

M_{max} – the peak torque of diesel engine,

n_M – rotational speed of a diesel engine on a rated condition,

n_{XX} – rotational speed of a diesel engine idling,

n_{min} – minimum rotational speed of a diesel engine.

Coefficients a^*, b^*, the included in datas of the formula, define declination of regulator branch of characteristic of diesel engine, which is shaped depending on parameters of regulator – mass of weights m and rigidity of spring c.

The carried out calculations under the formula (2) display correlation of energy indexes of diesel engine with amplitude of variable loading. The calculations were carried out for diesel engine D-180, regulator, arranged three springs, of different rigidity: 2800, 3240 and 3630 N/m and three weights of different mass: 200, 220 and 240 g. Three vibration amplitudes of velocity of gyration of diesel engine were given: 60, 80 and 100 rev/min.

The dependence of power of diesel engine on amplitude is shown in Fig. 2.

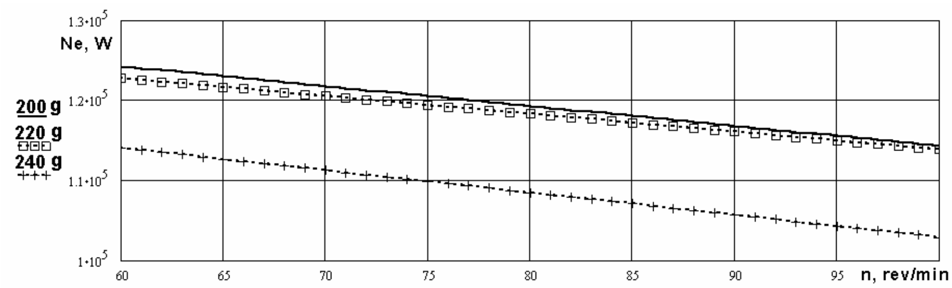

Fig. 2. Dependence of power of a diesel engine on a vibration amplitude velocities of gyration at different parameters of a regulator

The static performances of regulator shape declination regulator of a branch of velocity performance of diesel engine. The calculation of static performances of regulator is carried out under the formula:

$$\Delta Z = (K \cdot m \cdot \omega^3 - E_0)/\beta \cdot b \quad (2)$$

where:

ΔZ – height of uprise of clutch,
m – mass of weights, g,
ω – angular velocity of a bent shaft, rad/sec,
β – rigidity of spring,
E_0 – value of initial regenerating force, defined prestress strain of spring,
K, b – correction factors.

Under the sectional formula the theoretical static performances of regulator, introduced in Fig. 3 were calculated.

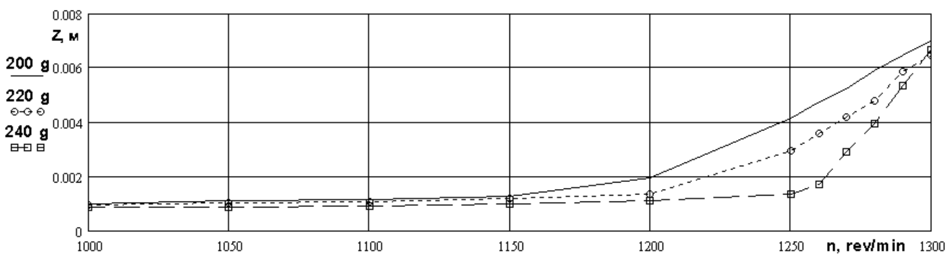

Fig. 3. Static performances at rigidity of spring 3240 N/m

After definition of static performances of regulator the immediate calculation of energy and dynamic indexes ETS of a tractor T-10 will be carried out. The calculations were carried out for conditions of share operation of diesel D-180 and hydrotransformer GTP-4804 at use of tractor in field conditions.

By results of calculation it is possible to select the best and worst combination of parameters of regulator (Fig. 4). The best condition – 4, that is regulator with mass of weights 200 g and rigidity of a spring 3240 N/m. Thus the magnitude of design value of effective power is 118 kW, that there is more base value of 116 kW to 1.02 times (overflow on 2%). The worst condition – 6: mass of weights of 240 g, rigidity of spring 3240 N/m. The design value of effective power here is 111 kW, that there is less base value on 4%. Thus rigidity of a spring – 3240 N/m, that is used on a base regulator.

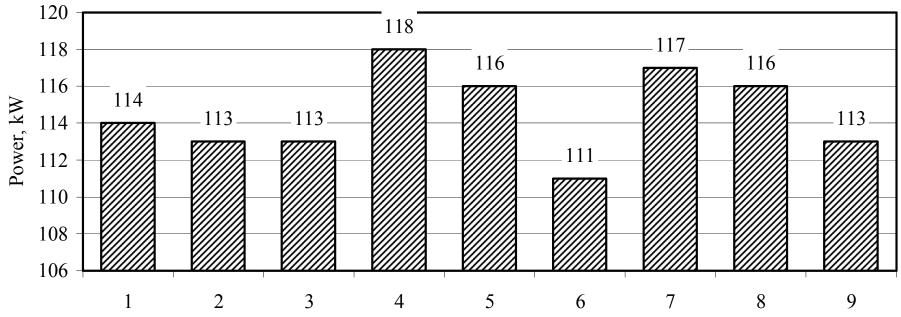

Fig. 4. Design values of effective power of diesel

The influence of frequency of variable loading on energy indexes of diesel engine was explored on expression linking expectation of power with an oscillation frequency of variable loading:

$$[M(N_e)](\omega) = 0.5[a \cdot \overline{\Omega}_K + b \cdot \overline{\Omega}_K^2 + 0.5\, b \cdot \Omega^2(\omega)] -$$
$$\pi\text{-}1[a \cdot 1\,\overline{\Omega}_K + b \cdot 1\,\overline{\Omega}_K^2 + 0.5\mathrm{b} \cdot 1\Omega 2(\omega)]\cdot \tag{3}$$
$$\cdot\arcsin[(\Omega n - \overline{\Omega}_K)/\Omega(\omega)] + (b \cdot 1/2\pi)(3\,\overline{\Omega}_K - \Omega n)\sqrt{\Omega^2(\omega) - (\Omega_n - \overline{\Omega}_K)^2}$$

where:

N_e – effective power of diesel engine,

$\overline{\Omega}_K$ – fixed value of velocity of gyration of diesel engine,

Ω_n – rated fixed value of velocity of gyration of diesel engine,

ω – oscillation frequency of variable loading.

With the help of sectional expression the frequency characteristic of expectation of effective power of a diesel engine can be explored. In particular, it is easily possible to point a value of an oscillation frequency of an angular velocity, at which the greatest lowering of expectation of effective power of diesel engine is observed.

On the basis of particular above than dependences of energy indexes ETS from parameters of regulator and loading there is necessity of optimization of datas of parameters with the purpose of the most effective operation of mobile aggregate. With this purpose the computational experiment in space of four factors was carried out. The computational experiment consists in calculation of energy indexes ETS of a tractor. The calculations were carried out for conditions of share operation of diesel engine D-180 of tractor T-10 and hydrotransformer GTP-4804 at use of tractor in field conditions.

With datas of computational experiment the equation of regression is found:

$$\begin{aligned} N_e(c, m, f, a) = &- 0.013 \cdot c^2 - 6.4 \cdot m^2 - 5490 \cdot f^2 - 11 \cdot a^2 + 44 \cdot c + \\ &+ 1864 \cdot m + 13574 \cdot f - 4795 \cdot a + 0.53 \cdot c \cdot a + \\ &+ 14.3 \cdot m \cdot a - 258 \cdot \mathrm{f} \cdot a - 1.87 \cdot c \cdot f + 24 \cdot m \cdot f + \\ &+ 0.21 \cdot c \cdot m - 136434 \end{aligned} \tag{4}$$

Maxima of sectional function – 123.3 kW at a rigidity of a spring 3392 N/m, mass of weights 209 g, amplitude of loading 6% and frequency of loading 0.7 Hz. The dependence of power on parameters of regulator and loading is shown in Fig. 5 and 6.

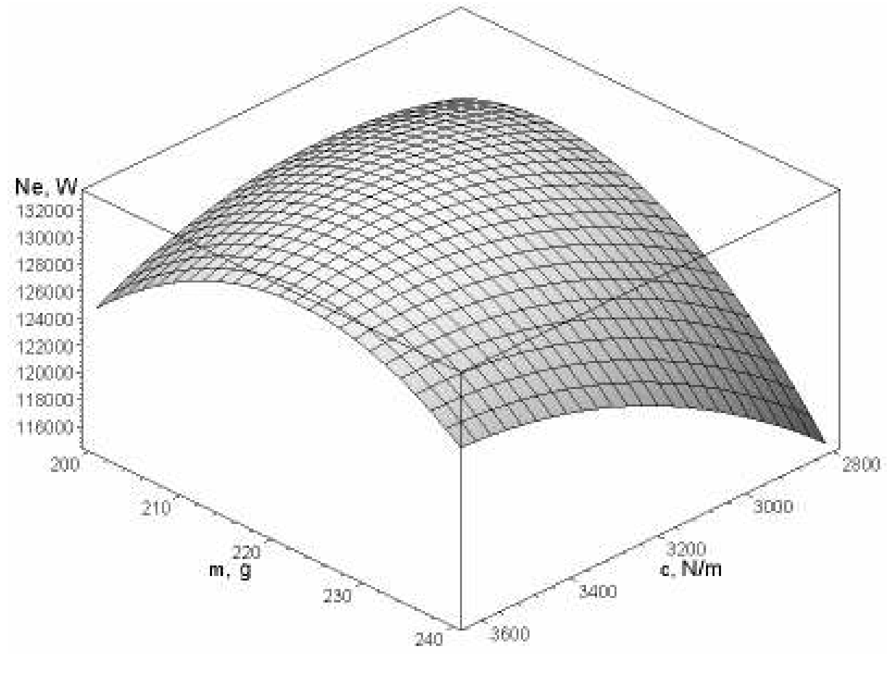

Fig. 5. Influence of parameters of regulator on power of diesel engine

At examination of operation of diesel engine in requirements of effect of variable loading twenty four experiments with three different masses of weights of regulator – 0.2 were carried out; 0.22; and 0.24 kg three by different springs rigidity 2800, 3240, 3630 N/m, three amplitudes 6, 8, and 10% and three frequencies of variable loading 0.3; 0.5 and 0.7 Hz. Standard parameters of regulator of diesel engine D-180 are mass of weights 220 g and rigidity of spring 3240 N/m.

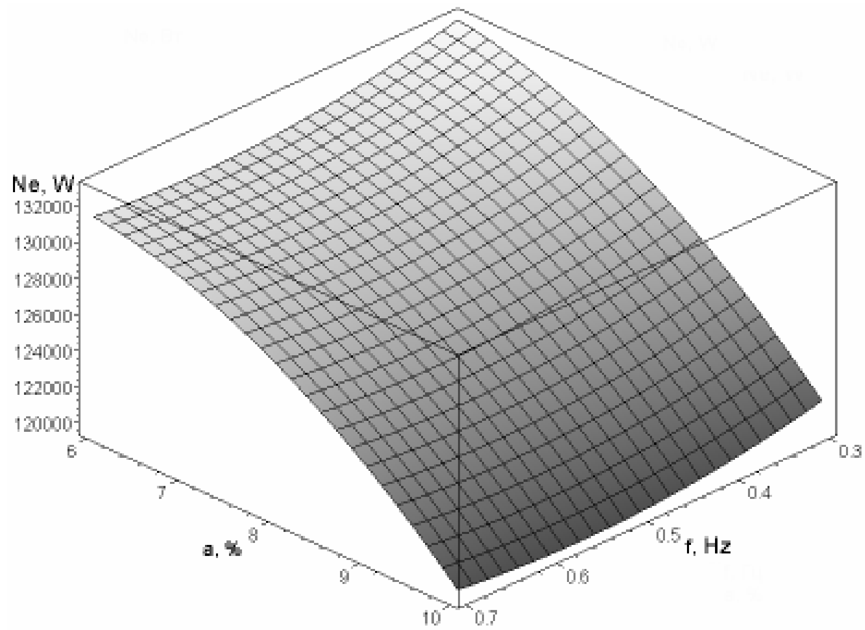

Fig. 6. Influence of parameters of loading on power of diesel engine

On the basis of experimental data the equation of a regression is obtained, on which the best values of data-ins are established.

In our case variable are a mass of weights, rigidity of a spring, amplitude and frequency of a loading, and response – value of effective power. Stationary values the coefficients of the equation of a regression further are determined. In result we obtain the equation:

$$\begin{aligned} N_e(c, m, f, a) = &- 0.017 \cdot c^2 - 15.2 \cdot m^2 + 23234 \cdot f^2 - 553 \cdot a^2 + \\ &+ 14.9 \cdot c + 5163 \cdot m + 39232 \cdot f + \quad + 5397 \cdot a - \\ &- 0.297 \cdot c \cdot a + 6.36 \cdot m \cdot a + 280 \cdot f \cdot a + \\ &+4.774 \cdot c \cdot f - 387 \cdot m \cdot f + 0.457 \cdot c \cdot m - 473348 \end{aligned} \tag{5}$$

Maxima of sectional function: 133 kW at rigidity of spring 3371 N/m, mass of weights of 218 g, frequency 0.3 Hz and amplitude 6%. The graphs of dependence of power from parameters of regulator both loading on experimental and calculation datas are submitted in Fig. 7.

The tendencies of influence of parameters of regulator and loading on power of diesel engine both in physical, and in computational experiment identical. The increase of power is scored at lowering vibration amplitude, magnification of rigidity of spring and some lowering of mass of weights (Fig. 7, c, d). The distinctions are observed only in influence of frequency (Fig. 7, a). As it is visible, in physical experiment the dip of power is observed at 0.59 Hz, while in computational experiment the power constantly grows with magnification of frequency. To this phenomenon there is following explanation:

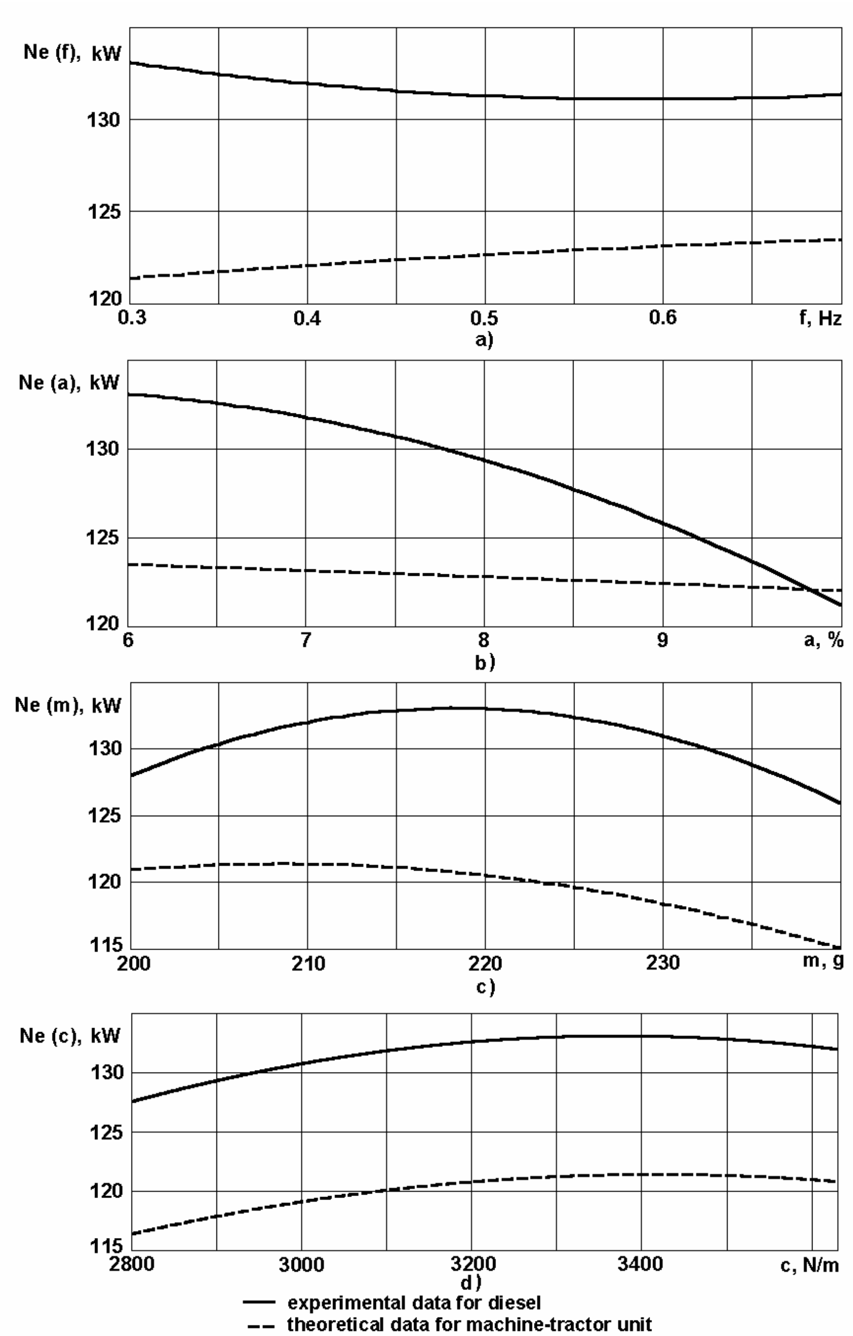

Fig. 7. Influence of parameters of regulator and loading on power

The resonance frequency for diesel engine on the stand – 0.59 Hz, and at it is observed dip of power. In computational experiment the reduced moment of inertia of tractor aggregate is more also resonance frequency less, hence in this case at frequencies 0.3; 0.5 and 0.7 Hz we are in afterresonance zone. Besides here it is impossible to eliminate influences of feeble elastic links in system of pump and turbine sprockets of the hydrotransformer.

OUTPUTS

1. As result of the theoretical analysis static and dynamic responses of mobile aggregate in requirements of effect of loading of probability character are established:

– Linear dependence of energy indexes from vibration amplitude of velocity of gyration of diesel engine.

– Dependence of power on an oscillation frequency of loading.

– Dependence of power on mass of weights of regulator.

– Dependence of power on rigidity of spring of regulator.

2. Experimentally is proved, that the power of diesel engine depend on frequency and vibration amplitude of velocity of gyration, and parameters of regulator (mass of weights and rigidity of spring). A maxima of power of diesel engine – 133.1 kW at mass of weights 218 g, rigidity of spring 3371 N/m, frequency 0.3 Hz and amplitude 6%.

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SUMMARY

The influence of variable loading and parameters of regulator on power of a diesel engine is considered. The results of experimental and theoretical examinations of operation of diesel engine are reduced at a variable loading and the mathematical model of diesel engine is created. The recommendations for heightening of an overall performance of diesel engine sectional.