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I. INTRODUCTION

The calculating scheme of the drive the milling cutter functional body (Figure 4) of the combined sowing machine may be various according to which parameters of the system are researched. To determine the required capacity developed by the engine for the driving of a milling machine, the degree of inequality of the drive ring and the inertia torque reduced by the flywheel it is sufficient to represent all the driving mechanisms of the research node as one absolutely solid mass by its inertia torque I_1, on which the reduced outer forces have impact, varying according to the given law (Figure 1).

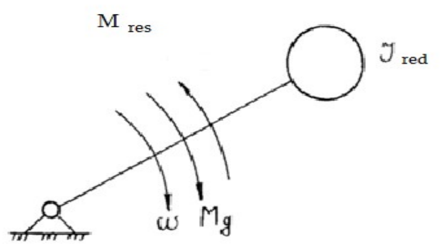

Figure 1: Single calculating scheme.

The equation of motion the rotating mechanisms of the drive the milling cutter functional body may be compiled using the Lagrange second order equation:

$$\frac{d}{dt} \bullet \frac{\partial T}{\partial q_i} - \frac{\partial T}{\partial q_i} + \frac{\partial \Pi}{\partial q_i} = M_i \quad (1)$$

Where T is system kinetic energy;

q_i - Generalized ortina;

Π - Potential energy of deformation of flexible elements;

M_i- i-mass added outer torque;

According to the torque s of research the milling body (1), the formula will take the following form:

$$I(f)\frac{d\omega}{dt} + \frac{\omega}{2} \bullet \frac{dI_{(\varphi)}}{dt} = M_g(\omega) - M_c(\varphi, \omega, t) \quad (2)$$

Where ω is the angular velocity of the drive ring;

$M_g(\omega)$- The torque of inertia of the engine, which depends on the speed of rotation and its value is selected according to the mechanical characteristics of the engine;

$M_c(\varphi, \omega, t)$- Resistance reduced torque , by common manner, which is depended on φ, ω, t magnitude, separately or on several simultaneously;

t - Time.

Equation (2) in the frequent cases is better to be presented by the following manner:

$$I(\varphi)\omega\frac{d\omega}{d\varphi} + \frac{\omega^2}{2} \bullet \frac{dI_{(\varphi)}}{d\varphi} = M_g(\omega) - M_c(\varphi, \omega, t) \quad (3)$$

It is known, that milling funct5ional bodies have the permanent inertia torque, then (2) and (3) equation may be represented by simplified manner:

$$I\frac{d\omega}{dt} = M_g(\omega) - M_c(\varphi, \omega, t) \quad (4)$$

or

$$I\frac{d\omega}{d\varphi} = M_g(\omega) - M_c(\varphi, \omega, t) \quad (5)$$

As can be seen from the above differential equation, in order to research the milling cutter functional body of the combined sowing machine it is necessary to know the regularity of the inertia torque for the corresponding mechanism, the regularity of the useful resistance torque on the milling cutter and the mechanical characteristics of the tractor engine.

(3)...(5) The equations are generally linear, which can be solved using approximately numerical and graphical methods.

Regarding the rotating working bodies driven by a diesel engine, (4) the torque developed by the engine to solve the equation on the driving shaft can be determined by the following equation

$$M_g(\omega) = A - B\omega \quad (6)$$

The parabola equation can be used to approximate the curve of the mechanical characteristics of the engine as well:

$$M_g(\omega) = A - B\omega^2 \quad (7)$$

Coefficients A and B are determined by the curve of the „$T - 25a$" diesel engine mechanical characteristics:

$$\begin{cases} A = \frac{M_{max} \cdot \omega_{nom}^2 - M_{nom} \cdot \omega_{max}^2}{\omega_{nom}^2 - \omega_{max}^2} \\ A = \frac{M_{max} - M_{nom}}{\omega_{nom}^2 - \omega_{max}^2} \end{cases} \quad (8)$$

where M_{max} is the maximum torque of the engine;

M_{nom} – torque;

ω_{max} and ω_{nom} are the angular velocities of the engine corresponding to th M_{max} and M_{nom} torques.

For the rotating functional bodies that are droven from a diesel engine to solve equation (4), the moment Mg (ω) developed by the engine on the driving shaft is better to be expressed by formula (7). According to such condition, (4) the differential equation can be written as follows:

$$I(\varphi)\omega\frac{d\omega}{d\varphi} + \frac{\omega^2}{2} \bullet \frac{dI_{(\varphi)}}{d\varphi} = A - B\omega^2 - M_c(\varphi) \quad (9)$$

(9) All members of the differential equation should be divided by small transformations on $I_{(\varphi)}\omega$ and we should obtain:

$$\frac{d\omega}{d\varphi} + f(\varphi)\omega + \frac{q_{(\varphi)}}{\omega} = 0 \quad (10)$$

$$f(\varphi) = \frac{\frac{1}{2} \bullet \frac{dI_{(\varphi)}}{d\varphi} + B}{I_{(\varphi)}} \quad (11)$$

$$q_{(\varphi)} + \frac{M_{c(\varphi)} - A}{I_{(\varphi)}} \quad (12)$$

If we introduce the marking ω^2=u, then (10) equation is transformed into a non-homogenous linear equation the second order of Bernoulli:

$$\frac{du}{d\varphi} + 2f_{(\varphi)}u = 2q_{(\varphi)} \quad (13)$$

Which common solution has the following form:

$$\omega_{(\varphi)} = \sqrt{exp - \left[2\int_0^{\varphi} f_{(\varphi)}d\varphi\right]\left\{C - 2\int_0^{\varphi} q_{(\varphi)}exp\left[2\int_0^{\varphi} f_{(\varphi)}d\varphi\right]d\varphi\right\}} \quad (14)$$

The angular velocity of the ring $\varepsilon_{(\varphi)}$ is determined by the following figures:

$$\varepsilon_{(\varphi)} = \frac{d\omega_{(\varphi)}}{dt} = \omega_{(\varphi)}\frac{d\omega_{(\varphi)}}{d\varphi} \quad (15)$$

or (14) through usage of the formula we will have

$$\varepsilon_{(\varphi)} = \left\{ f_{(\varphi)} \exp\left[-2\int_0^{\varphi} f_{(\varphi)} d\varphi\right]\left[C - 2\int_0^{\varphi} q_{(\varphi)} \exp\left(2\int_0^{\varphi} f_{(\varphi)} d\varphi\right) d\varphi\right] + q_{(\varphi)} \right\} \tag{16}$$

Depending on the angular velocity, the solution has the following form:

$$\omega_{(\varphi)} = \frac{1}{\sqrt{B}} \sqrt{In\left[\exp\left[-\int_0^{\varphi} f_{(\varphi)} d\varphi\right]\left\{C + A\int_0^{\varphi} \exp\left[f_{\varphi} df\right] df\right\}\right]} \tag{17}$$

The permanent value C can be determined by review the initial conditions when considering a particular machine.

For rotating type functional bodies the torque of reduced inertia of the engine is permanent, then we will have according to equations (11) and (12)

$$f_{(\varphi)} = \frac{B}{I} \quad q_{(\varphi)} = \frac{M_{c(\varphi)} - A}{I}$$

In the initial conditions $t = 0$; $\omega = \omega_0$The equation of the angular velocity of the drive ring (14) will take the following form:

$$\omega_{(\varphi)} = \sqrt{e^{-\frac{2B\varphi}{I}}\left\{\omega_0^2 - \frac{2(M_c - A)}{I}\int_0^{\varphi} e^{\frac{2B\varphi}{I}} d\varphi\right\}}$$

From which

$$\omega_{(\varphi)} = \sqrt{\omega_0^2 e^{-\frac{2B\varphi}{I}} - \frac{M_c - A}{B}\left(1 - e^{-\frac{2B\varphi}{I}}\right)}$$

In the purpose of qualitative loosening the soil by the milling cutter body in the sowing line it is required, that driving ring angular velocity be in the certain limits. Milling cutter functioning body angular velocity variation restriction may be reduced to the inertia torque directly by the selection manner, but if required by the extra mass (by installing the flywheel). Variation limits of the drive ring angular velocity is reflected through the coefficient of the motion inequality:

$$\delta = \frac{2(\omega_{max} - \omega_{\min})}{\omega_{max} + \omega_{min}} \tag{18}$$

In we add value of (17) in formula (18) and conduct transformations we will obtain:

$$\delta = \frac{\frac{2A - M_0}{2B} - \sqrt{\frac{(2A - M_0)^2}{2B} - 4\left(\sum_{n=1}^{m}\sqrt{\frac{a_n^2 + b_n^2}{4B^2 + n^2 I^2}}\right)^2}}{\sum_{n=1}^{m}\sqrt{\frac{a_n^2 + b_n^2}{4B^2 + n^2 I^2}}} \tag{19}$$

In order to detect the optimal I value of the reduced inertia torque according to formula (19) we have the following main cases:

1. When$\left(\frac{nI}{2B}\right)^2 = 1$,of I value is selected before it is not satisfying (19) equality condition.
2. when $\left(\frac{nI}{2B}\right)^2 \geq 1$ this condition is fair when $\rightarrow\infty$, so when we are taking the maximum number of rows to disperse a Fourier row. In this case the task is solved unequivocally. From the formula (19) we can obtain the following inequality.

$$I \geq \frac{B\left([\delta]^2+4\right)\sum_{n=1}^{m}\sqrt{\frac{a_n^2+b_n^2}{n^2}}}{[\delta](2A-M_0)} \tag{20}$$

If we consider, that $\frac{\delta^2}{4} \approx 0$, we will obtain

$$I \geq \frac{4B\sum_{n=1}^{m}\sqrt{\frac{a_n^2+b_n^2}{n^2}}}{[\delta](2A-M_0)} \tag{21}$$

Case, when $\left(\frac{nI}{2B}\right)^2 \leq 1$ is less possible.

The obtained calculation formula (21) will allow us to select the desired value I of the inertia torque of for the given value of the coefficient of movement inequality (δ).

It is possible to determine the Fourier series coefficients when the function is given analytically.

The law of variation the resistance torque is given in the form of a curve, which exact analytical figure is unknown. During determining the coefficients, the integration is changed to the final summary.

Through using the mathematical method of harmonized analysis we can obtain the following formulas:

$$M_0 = \frac{1}{m}(y_1 + y_2 + y_3 + \dots y_4)$$

$$\left.\begin{aligned} a_n &= \frac{2}{m}(y_1 \cos 1\Delta x + y_2 \cos 2\Delta x + y_3 \cos 3\Delta x + \dots + y_m \cos m\Delta x) \\ b_n &= \frac{2}{m}(y_1 \sin 1\Delta x + y_2 \sin 2\Delta x + y_3 \sin 3\Delta x + \dots + y_m \sin m\Delta x) \end{aligned}\right\} \tag{22}$$

Through using the mechanical characteristics of the tractor engine „T-25a“ (Fig. 2) and the graphic representation of the resistance torque (Fig. 3), we select the inertia torque of the milling cutter body of the combined sowing machine on the driving shaft.

According to the curve of the mechanical characteristics of the engine, the coefficients A and B are determined by formula (8).

$$A = \frac{93{\cdot}7.62-91{\cdot}5.34}{7.62-5.34} = 97.68\, nm$$

$$B = \frac{93-91}{7.62-5.35} = 0.88\, nm.sec^2$$

The corresponding section of magnitude O_{φ} (figure 3) is divided into 24 equal parts (m = 24), we measure the magnitude of the ordinates according to the corresponding split points. (21) The mean value of the resistance torque including in formula M_0 and the Fourier series coefficients are defined as follows:

$$M_0 = \frac{1}{24}(18.4 + 14.6 + 16.4 + ... + 9.7) = 26.229\, nm.$$

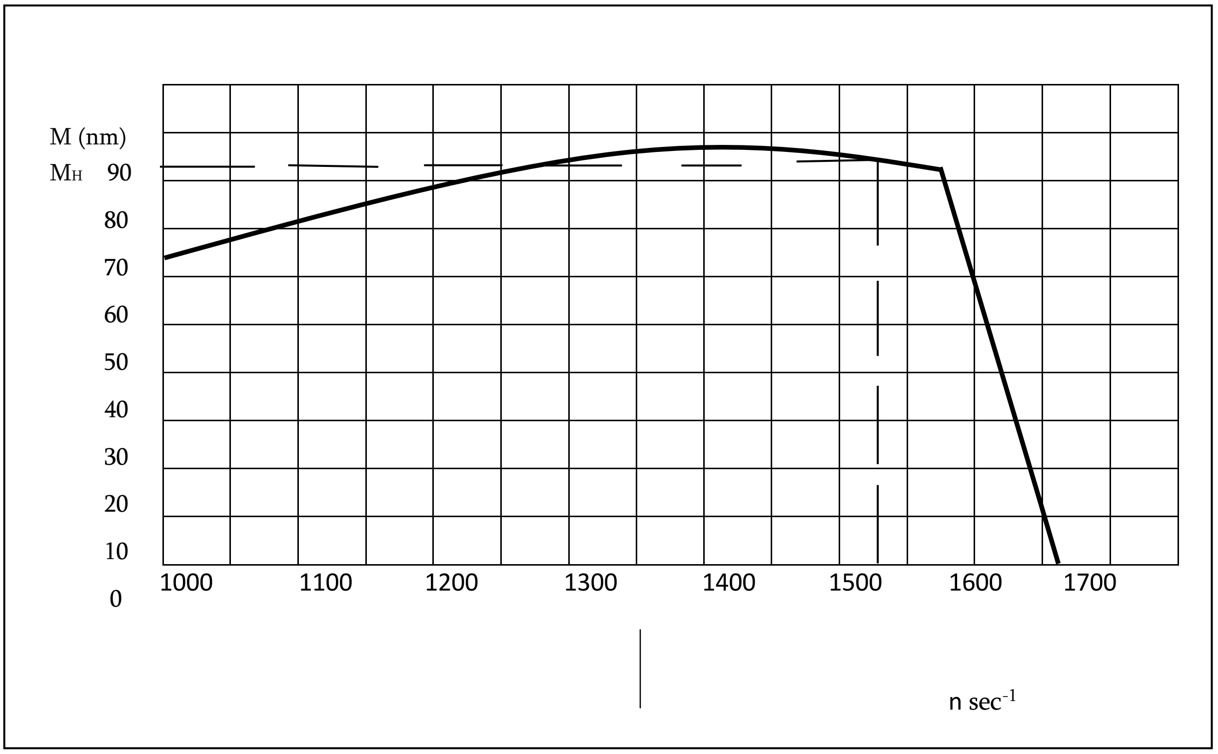

Figure 2: D-21A1 Diesel Engine Mechanical Characteristic.

First row harmonica

$$a_1 = \frac{2}{24}(17.774 + 12.643 + 11.594 + ... + 9.7) = -6.732 \text{ nm};$$

$$b_1 = \frac{2}{24}(4.765 + 7.3 + 11.594 + ... + 9.05) = -4.58 \text{ nm};$$

$$M_1 = \sqrt{a_1^2 + b_1^2} = \sqrt{(-6.732)^2 + (-4.58)^2} = 8.142 \text{ nm};$$

$$tga_1 = \frac{a_1}{b_1} = \frac{-6732}{-4.58} = 1.469 \qquad a_1 = 56^0;$$

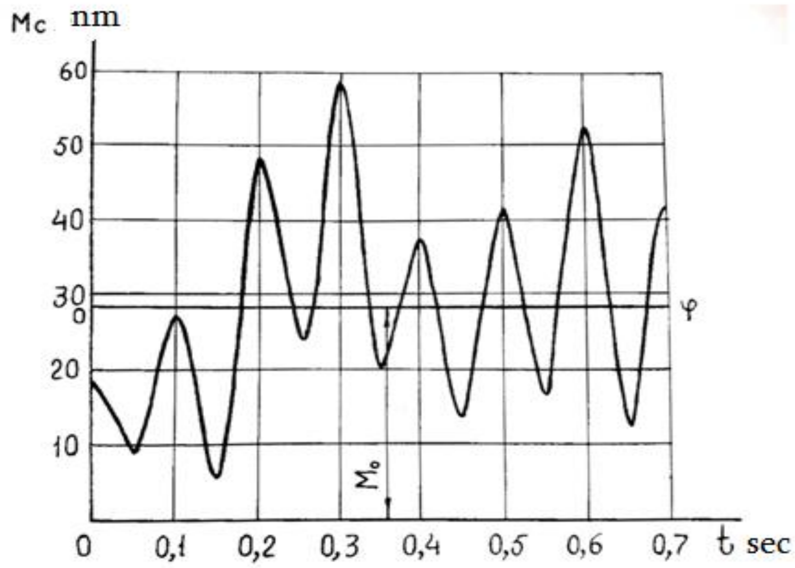

Figure 3: Resistance Torque Curve Valid on the Milling Cutter Functioning Body of the Combined Sowing Machine Resistance Torque Curve .

Second row harmonica

$$a_2 = \frac{2}{24}(15.934 + 7.3 - 7.65 + ... + 9.7) = 1.776 \text{ nm};$$

$$b_2 = \frac{2}{24}(9.2 + 12.643 + 16.4 + ... - 18.35) = -7.062 \text{ nm};$$

$$M_2 = \sqrt{a_2^2 + b_2^2} = \sqrt{(1.776)^2 + (-7.062)^2} = 7.448 \text{ nm};$$

$$tga_2 = \frac{a_2}{b_2} = \frac{1.776}{-7.062} = -0.251 \qquad a_2 = 166^0;$$

Third row harmonica

$$a_3 = \frac{2}{24}(13.008 - 11.594 - 15.3 - ... + 25.946) = -2.12 \text{ nm};$$

$$b_3 = \frac{2}{24}(13.008 + 14.6 + 11.594 - ... - 25.946) = 1.273 \text{ nm};$$

$$M_3 = \sqrt{a_3^2 + b_3^2} = \sqrt{(-2.12)^2 + 1.273^2} = 2.472 \quad \text{nm};$$

$$tga_3 = \frac{a_3}{b_3} = \frac{-2.12}{1.273} = -1.665 \quad a_3 = 121^0;$$

Fourth row harmonica

$$a_4 = \frac{2}{24}(9.2 - 7.3 - 16.4 - ... + 9.7) = -0.226 \quad \text{nm};$$

$$b_4 = \frac{2}{24}(15.934 + 12.643 - 13.249 - ... - 31.782) = 3.29 \quad \text{nm};$$

$$M_4 = \sqrt{a_4^2 + b_4^2} = \sqrt{(-0.266)^2 + 3.29^2} = 3.3 \quad \text{nm};$$

$$tga_4 = \frac{a_4}{b_4} = \frac{-0.266}{3.29} = -0.08 \quad a_4 = 175^0;$$

The equation of the curve the given resistance torque can be approximated as follows:

$$M_c = 26.229 + 8.142 \sin sin\left(x + 56^0\right) + 7.448 \sin sin\left(2x + 166^0\right) + 2.472 \sin sin\left(3x + 121^0\right) + 3.3sin(4x+175^0)$$

If we take into account, that $[\delta] = 0.16$ (20) according to the formula we will obtain:

$$I \geq \frac{4 \cdot 0.88\left[\sqrt{(-6.732)^2 + (-4.58)^2} + \sqrt{\frac{1.776^2+(-7.062)^2}{2^2}} + \sqrt{\frac{(-2.12)^2+1.273^2}{3^2} + \sqrt{\frac{(-0.226)^2+2.29^2}{2^2}}}\right]}{0.16 \cdot (297.68 - 26.229)} =$$

$$=1.742kg.m^2$$

In the result of the theoretical report there is obtained the reduced inertia torque value $I \geq 1.742\ kg.m^2$.

Following this through the experimental manner, there is determined the reduced inertia torque on the driving shaft of the tractor power, which may be reflected as follows:

$$I_1 = I_{01} + I_{02} \tag{23}$$

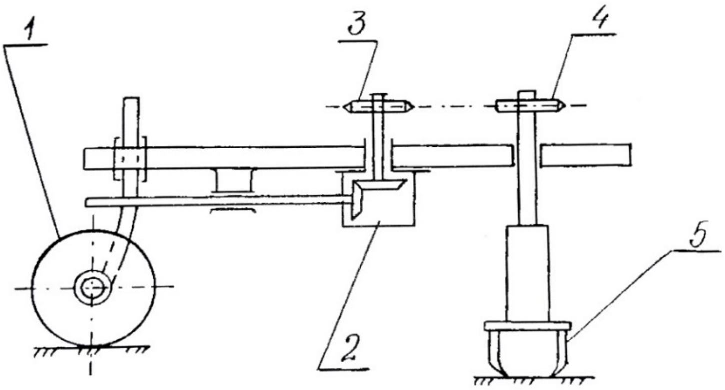

Figure 4: Kinematic Scheme of Driving the Milling Cutter Functioning Body of the Combined Sowing Machine

1-Support Wheel; 2- Code Reducer; 3- 3 and 4 Driving and Reveal Stars; 5- Milling Cutter; Total reduced inertia torque according to the formula (23) is equaled to":

$$I_1 = 1.80245 kg. m^2$$

II. CONCLUSION

Kinematic and dynamic parameters of the milling cutter functioning body of the combined sowing machine were determined through the analytical manner. Through applying the harmonized analysis method the reduced inertia torque optimal value ($I > 1.742$) of the milling cutter functioning body was determined. Through the experimental manner the reduced inertia torque optimal value $I_1 = 1.80245\, kg.\, m^2$ of the milling cutter functioning body was determined, which meets the given optimum condition, what is required for qualitative loosening the soil by the milling cutter body in the sowing line.

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