ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Issue 9 , September 2019

Dynamics of the Machine Unit with Drive Driving Mechanisms of Jin Cylinder

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ABSTRACT: The article presents the results of theoretical studies of machine units with a gin saw cylinder drive mechanism in the form of a single-mass rotary system. The laws of motion of the gin saw cylinder are obtained for various capacities, electric motor parameters and the moment of random technological resistance, as well as the moment of inertia of the saw cylinder.

KEYWORDS: Saw gin, cylinder, machine unit, random resistance, cotton, moment of inertia, mechanical characteristic, moment, angular velocity, acceleration, oscillation, unevenness.

I. INTRODUCTION

In gin-operated factories, saw gins include five machine units [1, 2]. In them, the saw cylinder receives rotational motion from the electric motor by means of a coupling [3].

The saw cylinder runs continuously, that is, in the actual system, the drive is rarely started and braked. In the results of [1, 2], a machine unit with a saw cylinder mechanism is taken into account in the form of two mass systems, taking into account the elastic transmission or coupling. Therefore, we considered transients only in the steady state operation of the saw gin. Moreover, in the machine unit, the electric motor was taken into account in the form of a mechanical dynamic characteristic proposed by I.S. Pinchuk [3, 4] which provides transients in the steady-state modes of operation of technological machines:

$$\frac{dM_{gb}}{dt} = 2M_k w_c - 2M_k p - w_c S_k M_{gb}\frac{d\varphi_{gb}}{dt} \qquad (1)$$

where, M_{gb}, M_k − torque on the motor shaft and its critical value; $\frac{d\varphi_{gb}}{dt}$ − angular speed of the motor rotor; ω_c− circular frequency of the network; p −the number of pole pairs of the motor; S_k − critical slip value.

The rated torque on the rotor of the electric motor is determined [5] from the expression:

$$M_н = 9550\frac{P_н}{n_н}\lambda \qquad (2)$$

where, $P_н, n_н$ −rated power consumption and rated frequency of rotation of a rotor of the engine; λ − coefficient characterizing the ratio of the critical and nominal moments, $\lambda = {M_к}/{M_н}$

The critical slip in an induction motor is determined from the expression according to [6]:

$$S_k = \lambda S_н(1 + \sqrt{1 - \frac{1}{\lambda^2}}) \qquad (3)$$

where, $S_н$ −normal slip value

$$S_н = 1 - \frac{\omega_н}{\omega_0} \qquad (4)$$

where, $\omega_н$ − value of the normal angular velocity of the engine;

ω_0 −rotor angular speed at ideal idle [6]:

$$\omega_0 = \frac{w_c}{P} = \frac{2\pi f_c}{P} \qquad (5)$$

f_c −network frequency, 50 Hz.

The calculated values of the parameters of the 4A280M8U3 induction electric motor are selected according to the data of well-known works [7, 8, 9]:

$$P_{gb} = 75\,kVt, n_{gb} = 730\,rpm;\ \omega_{gb} = 76{,}4\,c^{-1}, f_c = 50\,Hz,$$
$$\mathrm{P} = 4; \cos\varphi = 0{,}85;\ \omega_k = 220\,V;\ \lambda = 2{,}0;\ M_н = 674{,}5\,Nm;$$

$M_к = 1349\,Nm, S_н = 0{,}02;\ S_к = 0{,}075; J_n = 1{,}29\,kgm^2$–thereduced moment of inertia of the rotor of the motor, clutch and saw cylinder of gin 5DP-130 (4DP-130).

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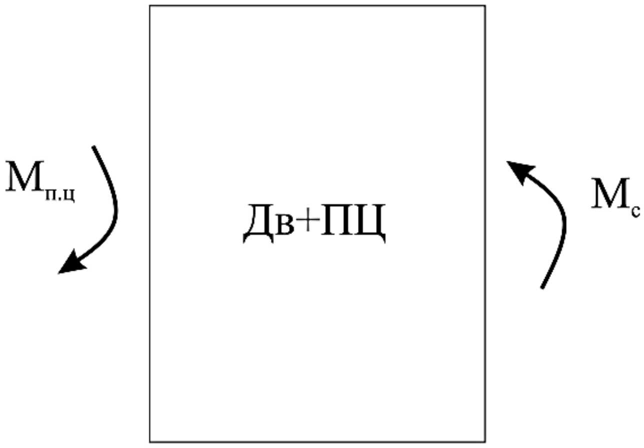
In this case, a dynamic model of a machine unit with a gin saw cylinder drive mechanism in the form of a single-mass rotational system is presented in Fig. 1.



$J_n, \dot{\varphi}_{p.s}$

Fig. 1. Dynamic model of a machine unit with a gin saw cylinder drive mechanism

According to the dynamic model (Fig. 1), the technological resistance from ginned cotton was taken into account according to the results of experimental studies [5]:

$$M_c = M_{p.s} \pm \delta(M_{p.s}) \quad (6)$$

where, $M_{p.s}$ –the average value of the moment of resistance on the shaft of the saw cylinder during ginning; $\delta(M_{p.s})$ –random moment components $M_{p.s}$ due to changes in resistance during ginning.

Using the Lagrange equation of the second kind [7], we obtain the following system of differential equations of a machine unit from the mechanisms of a gin saw cylinder:

$$\frac{dM_{gb}}{dt} = 2M_k\omega_c - 2M_k p\frac{d\varphi_{gb}}{dt} - \omega_c S_k M_{gb};\ J_n\frac{d^2\dot{\varphi}_{p.s}}{dt^2} = M_{gb} - \left[M_{p.s} \pm \delta(M_{p.s})\right] \quad (7)$$

For the numerical solution of the problem of the dynamics of a machine unit with a saw cylinder mechanism, the Runge-Kutta numerical method for the second-order differential equation in the form $S = \frac{d^2S}{dt^2} = F(t, S, S')$[8].

Studies have been given taking into account the inclusion of technological load from raw cotton with a random component. In this case, it is important to study changes in angular velocity, acceleration, and torque on the shaft of the gin saw cylinder. It should be noted that the rotor of the electric motor was also brought to the shaft of the saw cylinder, where the gear ratio between them is equal to unity. In fig. Figure 2 shows the patterns of change in angular velocity, acceleration, and torque on the shaft of the saw cylinder, taking into account changes in the random technological load from the raw cotton. Analysis of the patterns of change $\dot{\varphi}_{p.i}, \ddot{\varphi}_{p.m}$ and $M_{p.s}$ and shows that with an increase in the technological load from cotton (gin productivity) it leads to a decrease $\dot{\varphi}_{p.s}, \ddot{\varphi}_{p.i}$ and ascending $M_{p.s}$ their random fluctuations. It is known that an increase in torsional vibrations, that is, fluctuations in the angular velocity of the saw cylinder at certain intervals, leads to an intensification of the separation of fibers from cotton seeds (options a and b in Fig. 2). But, a significant increase in the amplitude of oscillations, especially random components of the angular velocity, angular acceleration of the saw cylinder can lead to increased damage to the fibers and seeds of cotton, but also to undesirable dynamic structural loads (option c, Fig. 2).

By processing the obtained regularities of the change in $\dot{\varphi}_{p.s}, \ddot{\varphi}_{p.s}$ and $M_{p.s}$, graphical dependences of the system parameters were constructed. Figure 3 shows the graphical dependence of the change in angular velocity and torque on the shaft of the gin saw cylinder on the change in technological load (average value). From them it is seen that with increases M_c nonlinearly decreasing $\dot{\varphi}_{p.s}$ and increases accordingly $M_{p.s}$.So, with an increase in the average value of the technological load from $2.8 \cdot 10^2$ Nm to $7.92 \cdot 10^2$ Nm, the average value of the angular velocity of the saw cylinder decreases from $0.739 \cdot 10^2$ s^{-1} to $0.631 \cdot 10^2$ s^{-1} at the reduced moment of inertia of the saw cylinder 1,05 $kg \cdot m^2$. In this case, the average value of

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 6, Issue 9 , September 2019

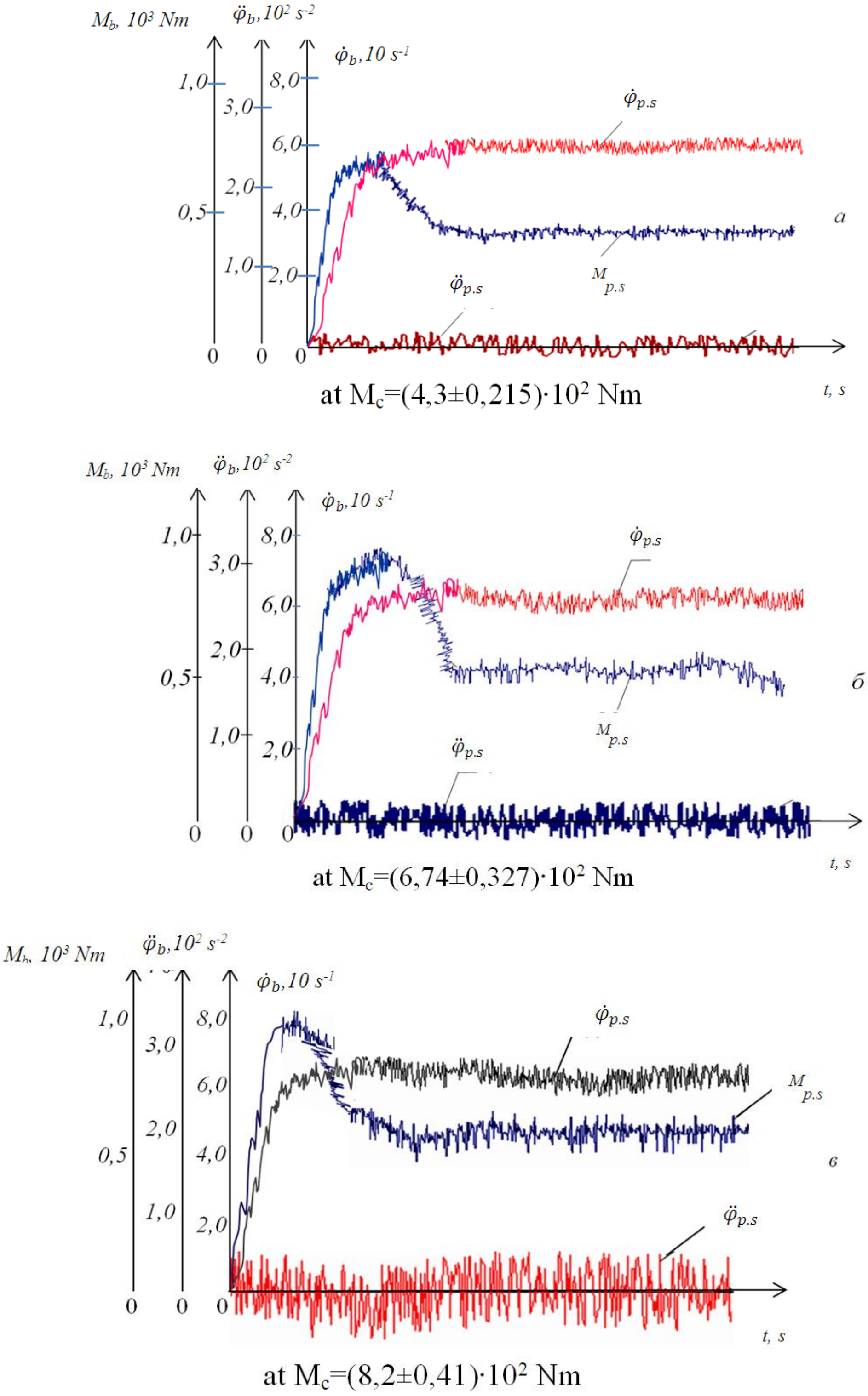
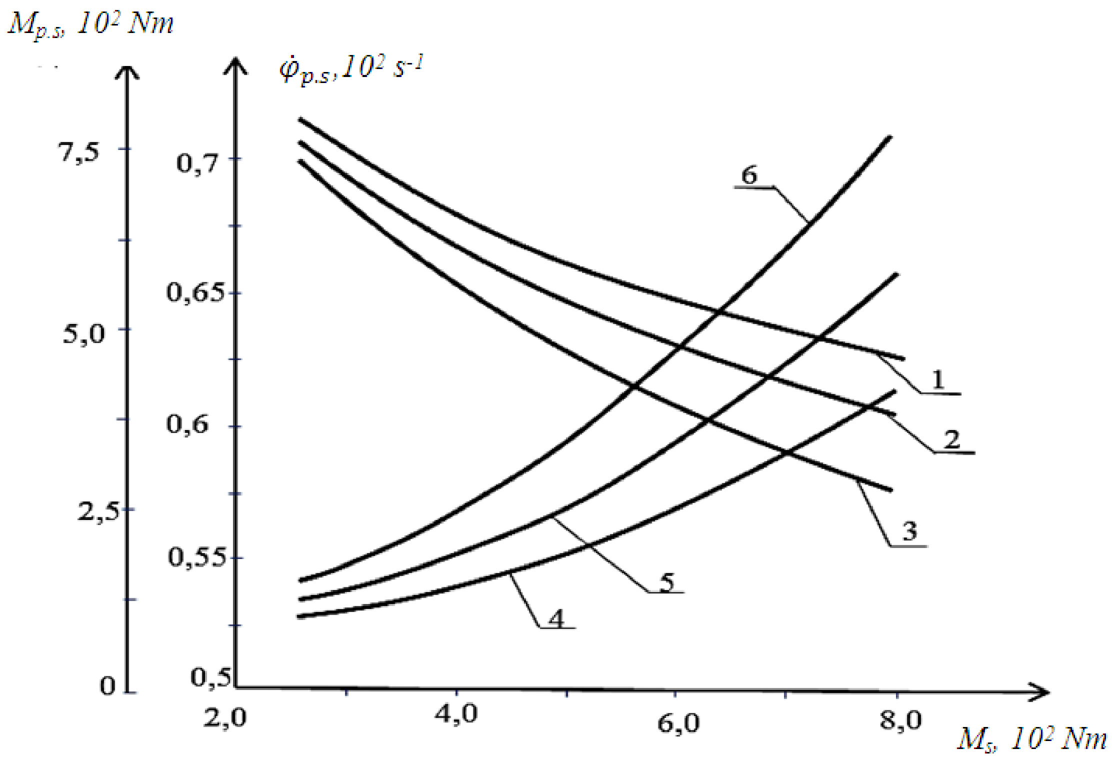


Fig. 2. Patterns of changes in angular velocity, acceleration, and torque on the shaft of a gin saw cylinder at various values of a random technological load from cotton.



where 1,2,3 -$\dot{\varphi}_{p.s} = f(M_s)$; 4,5,6 $- M_{p.s} = f(M_s)$; 1,4-and$J_n = 1{,}05\ kgm^2$; 2,5-and$J_n = 1{,}3\ kgm^2$; 3,6-and $J_n = 1{,}5 kgm^2$;

Fig. 3. Graphical dependences of the change in angular velocity, rotational moment on the shaft of the gin saw cylinder on the disturbing load from the ginned raw cotton

$M_{p.s}$increases from 1.07·10^2 Nm to 4.07·10^2 nm. This is explained by the fact that at small values of the reduced moment of inertia of the saw cylinder, the influence of the technological load on the change $\dot{\varphi}_{p.s}$ will be palpable. At the moment of inertia $J_n = 1{,}5\ kgm^2$, the angular velocity of the saw cylinder decreases to 0.592·10^2 s^{-1}, the torque increases to 7.108·10^2 Nm. It should be noted that a significant decrease in angular velocity leads to a decrease in ginning productivity. Therefore recommended values the parameters are:

$J_n = (1{,}0 \div 1{,}25) kg \cdot m^2; M_c \leq (4{,}5 \div 6{,}5) \cdot 10^2$Nm,under which$\dot{\varphi}_{p.s} \geq (6{,}7 \div 7{,}0) \cdot 10\ s^{-1}$

Important are the study of the range of fluctuations in the angular velocity, acceleration and loading of the saw cylinder, taking into account the random component of the technological load from cotton (see Fig. 4).

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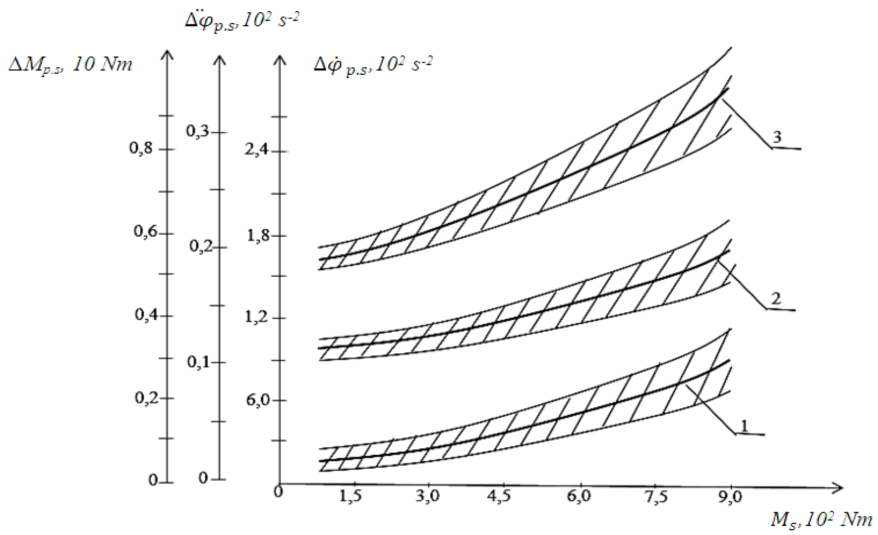


where, 1-$\Delta M_{p.s} = f(M_s)$; 2-$\Delta\dot{\varphi}_{p.s} = f(M_s)$; 3-$\Delta\dot{\varphi}_{p.s} = f(M_s)$ and $\delta M_s = (10 \div 12)\%M_s$

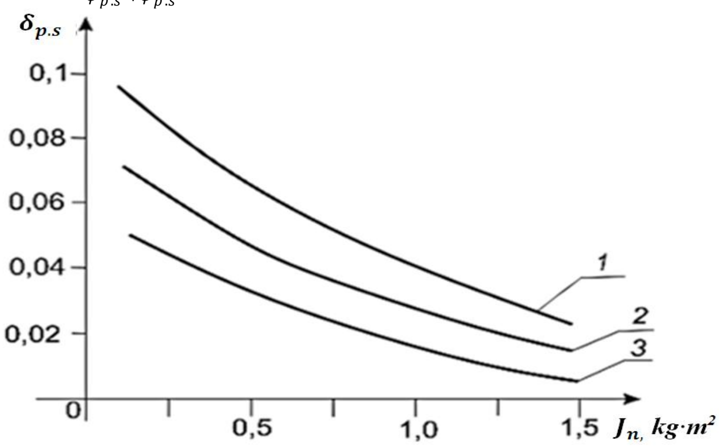
Fig. 4. Graphic dependences of the change in the range of fluctuations in the angular velocity, acceleration, and torque on the shaft of the gin saw cylinder as a function of changes in the technological load, taking into account the random component

The analysis of the obtained graphs in Fig. 4 shows that with an increase in the technological load, the swing range$\Delta\dot{\varphi}_{p.n}$, $\Delta\ddot{\varphi}_{p.m}$ and$M_{p.s}$tangible degree increases. So, with$M_s = 1{,}5 \cdot 10^2\ Nm$, $\Delta\dot{\varphi}_{p.s} = 3{,}89\ s^{-1}$, and$M_s = 8{,}92 \cdot 10^2\ Nm$the range $\Delta\dot{\varphi}_{p.s}$reaches up to 7.2 s^{-1}. The range of acceleration increases, respectively, $0.12\cdot10^2$ to $0.185\cdot10^2\ s^{-2}$.

Therefore, to reduce random fluctuations $\Delta\dot{\varphi}_{p.s}$, $\Delta\ddot{\varphi}_{p.s}$ and $\Delta\dot{M}_{p.s}$, it is advisable to reduce M_s to $(5.5\div 6.5)\cdot10^2$Nm, especially random component of the load, which depends on the uniformity of nutrition with cotton in the saw genie. The study of the dynamics of the machine unit allows the study of uneven angular velocity of the working bodies and the choice of parameters providing the required values of the uneven movement of the working bodies. In fig. Figure 5 shows the graphical dependences of the variation in the coefficient of unevenness of the angular velocity of the saw cylinder on the change in the reduced moment of inertia of the gin saw cylinder.

Wherein

$$\delta_{p.s} = 2\left(\frac{\dot{\varphi}_{p.s}^{Max} - \dot{\varphi}_{p.s}^{Min}}{\dot{\varphi}_{p.s}^{Max} + \dot{\varphi}_{p.s}^{Min}}\right) \quad (8)$$



where,, 1-and$M_s = 4{,}3 \cdot 10^2 Nm$; 2-and$M_s = 6{,}74 \cdot 10^2 Nm$ 3-and$M_s = 8{,}21 \cdot 10^2 nm$

Fig. 5. Graphical dependences of changes in the coefficient of unevenness of the angular velocity of the saw cylinder on the variation of its reduced moment of inertia for various values of the process load

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It is known [1, 2] that the greater the moment of inertia of the working body, the lower the coefficient of unevenness of the angular velocity. For the case under consideration, it is recommended to select $\delta \leq (0{,}08 \div 0{,}09$ to ensure $J_n = (1{,}0 \div 1{,}25) kg \cdot m^2$.

II.CONCLUSION

The dynamic and mathematical models of a machine unit with a drive mechanism for a gin saw cylinder are compiled. Taking into account the mechanical characteristics of the asynchronous electric motor and the technological load from the ginned cotton. On the basis of a numerical solution of the problem, regularities in the change in the angular velocity, acceleration, and rotational moment on the shaft of the saw cylinder are obtained, taking into account the change in the random technological load from the ginned raw cotton.

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