Study of the machine unit of the saw gin seed-retracting device

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Abstract. The article provides the results of research on the machine unit of the seed-retracting device of the saw gin. The equations of motion of the machine unit of the seed-retracting device of the saw gin were derived and the moments of inertia of the electric motor and the seed-retracting device were experimentally determined. As a result of research, the critical values of the driving moment of an electric motor (according to the characteristics of M.M. Sokolov and others) and the angular acceleration of the saw cylinder and the time of the transient process were stated. It was determined that the maximum value of the angular velocity of the seed-retracting device reaches 53.191 rad/s at \(t=2.061\) s, delaying the electric motor velocity by 0.4 s, since the maximum value of the angular velocity of the electric motor reaches 130.598 rad/s at \(t=1.605\) s.

1. Introduction

It is known that the raw cotton, after being picked by cotton harvesters [1, 2], is dried and cleaned before ginning, and the properties of cotton are of great importance [3, 4].

In the ginning process, the fibers are torn from the seeds using the saw blade teeth, forming a saw cylinder with the cushions between the saws [5].

To increase the productivity and energy efficiency of the saw gin, a seed-retracting device is additionally installed (figure 1), which increases the rotational speed of the raw material roll [6].

However, to provide an effective use and technological mode of operation, it is necessary to study the pattern of change in the frequency and nonuniform rotation of the rotor of the electric motor and the seed-retracting device, depending on the elastic-dissipative parameters of the belt drive, the moment of inertia and resistance of electric motor and the seed-retracting device at their various values using the equation of motion of the machine unit.

Along with this, it is necessary to study the dynamic characteristics and to find rational parameters of the drive of the seed-retracting device and establish ways to reduce the non-uniform rotation of the seed-retracting device and the power consumption of electric motor, which provides an improved seed removal from the working chamber of the saw gin through the seed-retracting device. For this, it is...
necessary to take into account the elasticity of the links and damping factors (dissipation) of the drive; the elasticity and dissipation of the supports are not taken into account due to the generalization of the system coordinates.

![Image](image_url)

**Figure 1.** View of the seed-retracting device inside the working chamber.

The study in [7] proposes a systematic approach to the modeling of machine units and outlines the general principles. The machine unit is considered as an electronic control subsystem, an electric drive subsystem and a mechanical working subsystem.

In the monograph by I.I. Vulis [8], modern methods of calculating the vibrations of machines, including mechanisms of cyclic action (lever, cam, step actions, etc.) are described. To reduce the complexity of the calculation, a less idealized design scheme is proposed, in which the corresponding element is considered as a subsystem with distributed parameters.

In [5], the dynamic characteristics of the saw gin are considered as subsystems with lumped and distributed parameters. The graphs constructed as a result of studying the machine unit made it possible to determine the maximum values of the relative rotation angle and the rotation angle of the saw cylinder shaft under torsion.

The value of the multiplicity of the starting torque relative to the rated one is 1.5–6. However, for the asynchronous motor used here, it is 2 [9]. It follows that the maximum load on the electric motor is observed at the time of starting.

2. Materials and methods.
When deriving differential equations of motion of the seed-retracting device, the Lagrange equation of the second kind [5] was used.

Kinematic diagram (a) and dynamic model (b) of the machine unit of the seed-retracting device are shown in figure 2, where \( \mathcal{J}_D \), \( \mathcal{J}_C \) are the moments of inertia of the electric motor and the seed-retracting device, respectively, kg\(\cdot\)m\(^2\); \( M_D \), \( M_C \), - the moments of loads acting on the rotating shaft of the electric motor and the seed-retracting device, respectively, N\(\cdot\)m; \( c \) is the stiffness of the belt drive, N\(\cdot\)m/\(\text{rad}\); \( \vartheta \) are the coefficients of dissipation of the belt transmission, N\(\cdot\)m\(\cdot\)s/\(\text{rad}\); \( \dot{\phi}_D \), \( \dot{\phi}_C \), are the angular velocities of rotating masses of the system, \( \text{s}^{-1} \); \( i_{DC} \) are the belt drive gear ratios.

The drive of the seed-retracting device of the saw gin consists of a belt drive. The following kinematic relationships are valid for the drive of the seed-retracting device:

\[
i_{DC} = \frac{\dot{\phi}_D}{\dot{\phi}_C} = \frac{D_D}{D_C} = \frac{130}{247} = 0.526
\]

(1)

where \( D_D \) and \( D_C \) are the diameters of the electric motor pulley and the seed-retracting device, respectively, mm.
For the generalized coordinates, we take the angular velocities $\dot{\phi}_D$, $\dot{\phi}_C$ of rotating masses of the electric motor and the seed-retracting device.

Substituting certain terms (as in [5]) in the Lagrangian equations, we obtain a system of differential equations of motion of the machine unit of the seed-retracting device in the general form:

$$
\begin{align*}
\mathcal{L}_D \cdot \dot{\phi}_D &= M_D - c \cdot (\phi_D - i_{DC} \cdot \phi_C) - \epsilon_c \cdot (\phi_D - i_{DC} \cdot \phi_C) \\
\mathcal{L}_C \cdot \dot{\phi}_C &= c \cdot i_{DC} \cdot (\phi_D - i_{DC} \cdot \phi_C) + \epsilon \cdot i_{DC} \cdot (\phi_D - i_{DC} \cdot \phi_C) - M_C
\end{align*}
$$

When investigating the dynamic parameters of the seed-retracting device, we used the dynamic mechanical characteristics of an asynchronous electric motor. These characteristics take into account both the electromagnetic transient starting processes and the steady motion described by a system of differential equations containing the components of the stator and rotor flux linkage vector at the synchronous rotation velocity of the coordinate axes. It has the following form [10]:

$$
\begin{align*}
M_D &= \frac{3 \cdot P \cdot K_\omega \cdot \omega_S}{2 \cdot \sigma \cdot x_s} \left( \psi_{x_2} \cdot \psi_{y_1} - \psi_{x_1} \cdot \psi_{y_2} \right) \\
\psi_{x_1} &= U_m \cdot \cos \gamma - \omega_S \cdot \alpha_S \cdot \psi_{x_1} + \omega_c \cdot \alpha_c \cdot \psi_{y_1} + \alpha_S \cdot \psi_{x_1} - \omega_c \cdot \psi_{y_1} \\
\psi_{y_1} &= U_m \cdot \sin \gamma - \omega_S \cdot \alpha_S \cdot \psi_{x_1} + \omega_c \cdot \alpha_c \cdot \psi_{y_1} + \alpha_S \cdot \psi_{x_1} - \omega_c \cdot \psi_{y_1} \\
\psi_{x_2} &= -\omega_S \cdot \alpha_S \cdot \psi_{x_1} + \omega_c \cdot \alpha_c \cdot \psi_{y_1} + \alpha_S \cdot \psi_{x_1} - \omega_c \cdot \psi_{y_1} \\
\psi_{y_2} &= -\omega_S \cdot \alpha_S \cdot \psi_{x_1} + \omega_c \cdot \alpha_c \cdot \psi_{y_1} + \alpha_S \cdot \psi_{x_1} - \omega_c \cdot \psi_{y_1}
\end{align*}
$$

where $\psi_{x_1}$, $\psi_{y_1}$ are the components of the generalized vector of stator flux linkages along the $x$ and $y$ axes, rotating at a synchronous speed; $\psi_{x_2}$, $\psi_{y_2}$ are the components of the generalized vector of rotor flux linkages along the $x$ and $y$ axes; $K_s=x_s/\alpha_s=0.94$; $K_c=x_c/\alpha_c=0.90$ are the coefficients equal to the ratios of the total reactive resistance of mutual induction $x_s=45.27 \text{ ohm}$ to the total reactive resistance of the stator $x_s$ and rotor $x_r$; $\alpha_S$, $\alpha_c$ are the coefficients equal to the ratios of the total resistance of the stator phase $r_j=2.26 \text{ ohm}$ and the rotor phase $r_2=2.35 \text{ ohm}$ to the total reactive resistance of the stator $x_S$ and the rotor $x_r$; $\sigma=\omega_S/\sigma=0.303$; $\sigma=r_2/x_S=0.047$; $\sigma=\omega_S/\sigma=0.304$; $\sigma=1-K_\omega=0.154$; $x_S=x_s+x_2=48.38 \text{ ohm}$ is the synchronous reactive resistance of the stator winding, that takes into account the magnetic coupling with the other two phase stator windings; $x_2=48.38 \text{ ohm}$ is the synchronous reactive resistance of the rotor winding, that takes into account the magnetic coupling with the other two phase stator windings; $x_s=3.11 \text{ ohm}$ is the leakage inductive reactance of the stator winding; $x_2=4.81 \text{ ohm}$ is the leakage inductive reactance of the rotor winding [9].

Next, we determine the passport parameters and coefficients of the asynchronous motor 4A112MV8UZ (taken for the purpose of unification of production) [9]: $N = 3.0 \text{ kW}$ - rated power of the motor; $n = 750 \text{ rpm}$ - rated speed of the engine rotor; $M_{cr} = 77.95 \text{ Nm}$ - critical moment on the motor.
rotor shaft; \( M_n = M_{cr}/2 = 38.98 \text{ Nm} \) - rated torque on the motor rotor shaft; \( f_m = 50 \text{ Hz} \) - mains frequency; 

\( U_m = 220 \text{- rated phase voltage} \); 

\( \eta = 0.83 \) - motor efficiency; 

\( \cos \phi = 0.74 \) - rated power factor of the motor; 

\( \omega_o = 78.54 \text{ s}^{-1} \) - synchronous speed of the motor rotor; 

\( \omega_n = 76.97 \text{ s}^{-1} \) - rated speed of the engine rotor; 

\( S_n = (\omega_o - \omega_n)/\omega_o = 0.02 \) - rated value of motor slip; 

\( S_k = 0.075 \) - critical value of motor slip; 

\( P = 4 \) - the number of pole pairs; 

\( I_{r,ph} = 7.77 \text{ A} \) - rated phase current.

The moments of inertia of the electric motor (figure 3) and seed-retracting device (figure 4) were determined by the acceleration method used to determine the moment of inertia of the bodies of rotation.

**Figure 3.** Bench to determine the moment of inertia of an electric motor.  
**Figure 4.** Bench to determine the moment of inertia of the seed-retracting device.

The working bodies under investigation were mounted on bearings, so, the experiments were conducted directly on the saw gin. For this, a thread was wound on the pulley, with weights \( G_1 \) and \( G_2 \) suspended at its end. These weights were lifted to a height of \( h \). From two experiments with different weights, the fall times \( t_1 \) and \( t_2 \) were video recorded and the accelerations \( W_1 \) and \( W_2 \) were determined. After that, the required moments of inertia of the working bodies of the seed-retracting device of the saw gin were obtained from the following equation.

\[
\Im = \left( G_1 \cdot \left( 1 - \frac{W_1}{g} \right) - G_2 \cdot \left( 1 - \frac{W_2}{g} \right) \right) \cdot \frac{r^2}{(W_1 - W_2)}
\]  

(4)

Where: \( G = m \cdot g \) – is the gravity, \( N \); \( m \) is the load weight, kg; \( g = 9.81 \text{ m/s}^2 \) is the free fall acceleration; \( r \) is the pulley radius, m; \( t \) is the time of load lowering, s; \( h \) is the height of the load lowering, m.

The falling load accelerations were set in the following form

\[
W_1 = \frac{2 \cdot h}{t_1}, \quad W_2 = \frac{2 \cdot h}{t_2}
\]  

(5)

The experimental results are presented in tables 1 and 2.

As a result of experiments, the following moments of inertia were obtained for the working bodies: the engine rotor (table 1) with a pulley \( \Im_D = 0.0378 \text{ kg m}^2 \) and a seed-retracting device (table 2) with a pulley \( \Im_c = 1.14 \text{ kg m}^2 \).

The stiffness of belt drives for a belt (section B) is determined according to [11]:

4
where \( a \) is a coefficient that takes into account the effect of pre-tension for V-belt transmissions under normal operation \( a=2; R \) is the radius of the pulley, \( m; E = 42 \cdot 10^6 \text{N/m}^2 \) is the elastic modulus; \( F \) is the cross-sectional area of the belt, \( m^2; l_p \) is the belt length, \( m \).

### Table 1. Results of experimental determination of the moment of inertia of the electric motor (at \( h=1 \text{m} \) and the pulley radius \( r=0.065 \text{m} \)).

| No. of repetitions | Load mass \( m \), kg | Gravity of loads \( G \), N | Time of load falling \( t \), s | Acceleration of falling loads \( W \), m/s\(^2 \) | Moment of inertia of the electric motor \( J_1 \), kg·m\(^2 \) |
|-------------------|----------------------|---------------------------|------------------------------|-----------------------------------|-----------------------------------|
| 1                 | 0.2                  | 1.9612                    | 4.72                         | 0.0898                            | 0.0381                            |
|                   | 0.3                  | 2.9418                    | 3.21                         | 0.1941                            | 0.0381                            |
| 2                 | 0.3                  | 2.9418                    | 3.21                         | 0.1941                            | 0.0373                            |
|                   | 0.4                  | 3.9224                    | 2.59                         | 0.2981                            | 0.0379                            |
| 3                 | 0.4                  | 3.9224                    | 2.59                         | 0.2981                            | 0.0379                            |
|                   | 0.5                  | 4.9030                    | 2.24                         | 0.3986                            | 0.0379                            |

### Table 2. Results of experimental determination of the moment of inertia of the seed-retracting system (at \( h=1 \text{m} \) and the pulley radius \( r=0.1235 \text{m} \)).

| No. of repetitions | Load mass \( m \), kg | Gravity of loads \( G \), N | Time of load falling \( t \), s | Acceleration of falling loads \( W \), m/s\(^2 \) | Moment of inertia of the seed-retracting system \( J_2 \), kg·m\(^2 \) |
|-------------------|----------------------|---------------------------|------------------------------|-----------------------------------|-----------------------------------|
| 1                 | 6                    | 58.836                    | 3.95                         | 0.1282                            | 1.1308                            |
|                   | 6.5                  | 63.739                    | 3.26                         | 0.1882                            | 1.1308                            |
| 2                 | 6.5                  | 63.739                    | 3.26                         | 0.1882                            | 1.1569                            |
|                   | 7                    | 68.642                    | 2.85                         | 0.2462                            | 1.1224                            |
| 3                 | 7                    | 68.642                    | 2.85                         | 0.2462                            | 1.1224                            |
|                   | 7.5                  | 73.545                    | 2.56                         | 0.3052                            | 1.1496                            |
| 4                 | 7.5                  | 73.545                    | 2.56                         | 0.3052                            | 1.1496                            |
|                   | 8                    | 78.448                    | 2.35                         | 0.3621                            | 1.1496                            |

The damping coefficients of belt drives for the belt section (section B) [12] are:

\[
\alpha = \phi \cdot \frac{c}{2\pi(2\pi/T)} = \frac{0.5 \cdot c \cdot T}{(2\pi)^2} = \frac{0.5 \cdot 42.96 \cdot 0.321}{(2\pi)^2} = 0.175 \text{N·m·s/ran}\]

Where \( \phi=0.5 \) is the coefficient for transmission mechanisms taken within \( 0.2 < \phi < 0.6 \); \( T \) is time, \( s \).

Technological load. \( M_i=M_{\text{in}} + M_0 \cos(\pi \omega t + \varphi_0) \) (here \( M_{\text{in}}=35.67 \text{N·m}; M_0=3.33 \text{N·m}; \omega=\pi/30 \text{rad/s}; t \) – time; \( \varphi_0 \) - initial phase) is the average load acting on the seed-retracting device.

### 3. Results and discussion

The implementation of the equations of motion of the saw cylinder machine unit (2) with the characteristic of the drive motor (3) made it possible to establish the change pattern in the driving moment of the asynchronous electric motor (figure 5), the angular velocity of the electric motor rotor and the seed-retracting device as a function of time (figure 6), and the change in power consumption of electric motor (figure 7).

The following parameters of the system were used: technological load acting on the rotating seed-retracting device \( M_i=M_{\text{in}} + M_0 \cos(\pi \omega t + \varphi_0) \) (here \( M_{\text{in}}=35.67 \text{N·m}; M_0=3.33 \text{N·m}; \omega=\pi/30 \text{rad/s}; t \) – time; \( \varphi_0 \) - initial phase); elastic-dissipative parameters \( (c=42.96 \text{N/m/ran} \text{and} \alpha=0.175 \text{N·m·s/ran}) \) of
the belt drive, the moment of inertia of the electric motor ($\mathcal{J}_D=0.0378 \text{ kg} \cdot \text{m}^2$) and the seed-retracting device ($\mathcal{J}_C=1.14 \text{ kg} \cdot \text{m}^2$).

![Figure 5](image)

**Figure 5.** Change in the driving moment of an asynchronous electric drive as a function of time.

![Figure 6](image)

**Figure 6.** Change in the angular velocity of the rotor of electric motor ($\omega_D$) and the seed-retracting device ($\omega_C$) as a function of time.

![Figure 7](image)

**Figure 7.** Change in power consumption of the electric motor as a function of time.
4. Conclusions
In general, the study of machines and machine units made it possible to establish the dynamics of starting the electric motor and torsional vibrations of the seed-retracting device.

The study of the machine unit of the seed-retracting device showed that the critical driving moment of the electric motor (according to the characteristics of Sokolov M.M. and others) is $657.96 \text{ N \cdot m}$, the transient process lasts for 5.7 s, and the maximum value of the angular velocity of the seed-retracting device reaches $53.191 \text{ rad/s}$ at $t = 2.061 \text{ s}$, lagging behind the electric motor by 0.4 s since the maximum value of the angular velocity of the electric motor reaches $130.598 \text{ rad/s}$ at $t = 1.605 \text{ s}$.

The study of the power consumption of the seed-retracting device showed that at the end of the transient process (at $t = 5.5 \text{ s}$) the consumption was 0.055 kW, and after cotton feeding (at $t = 6 \text{ s}$) the power consumption was within 0.750-2.164 kW. In the steady state of electric motor operation (at $t = 10 \text{ s}$), the power consumption of the electric motor was in the range of 1.47-1.59 kW.

References
[1] Rizaev A A, Yuldashev A T and Kuldoshev D A 2020 Model and calculation development of productivity of cotton harvesters IOP Conf. Ser.: Mater. Sci. Eng. 919(3) 032013
[2] Rizaev A A, Yuldashev A T, Kuldoshev D A, Abdillaev T and Ashurov N 2020 Advance of spindle drum and frontality of active spindle surface IOP Conf. Ser.: Mater. Sci. Eng. 883(1) 012157
[3] Parpiev A, Sharakhmedova M and Parpiev A 2020 Analysis of deformation of Cotton in Technological processes Int. J of Emerging Trends in Engineering Research 8(9) 6618-22
[4] Bucinskas V, Sesok N, Sesok A, Iljin I, Sutinys E, Subacius R, Bureika G and Warsza Z L 2016 Experimental Definition of Compressive Stiffness of Cotton Flock Challenges in Automation, Robotics and Measurement Techniques 881-91 Retrieved from: https://link.springer.com/book/10.1007/978-3-319-29357-8
[5] Mukhammadiev D M, Ibragimov F K and Mukhammadiev T D 2020 Modeling the Motion of a Saw Ginning Machine J. of Machinery Manufacture and Reliability 49(3) 256-62
[6] Mukhammadiev D M 2014 Dynamics of machine units of saw gin with seed retractor device and condenser with pulse air stream (Tashkent)
[7] Steinhauser J and Milan N 2015 Principles of Modelling of Machine Aggregates Acta Technica Corvininesis – Bulletin of Engineering Research 8(4) 57-9
[8] Vulfson I 2015 Dynamics of Cyclic Machines (Heidelberg, New York, Dordrecht, London: Springer) p 410
[9] Kravchik A E, Shlaf М М, Afonin V I and Sobolevskaya E A 1982 Asynchronous motors of series 4А (Moscow: Energoizdat) p 504
[10] Sokolov M M, Petrov L P, Masandilov L B and Ladenzon V A 1967 Electromagnetic transient processes in an asynchronous drive (Moscow: Energy) p 200
[11] Rivin E I 1966 Machine drive dynamics (Moscow: Mashinostroenie) p 204
[12] Astashev V K, Babitsky V I and Kolovsky M Z 2000 Dynamics and Control of Machines (Heidelberg, New York, Dordrecht, London: Springer) p 233