Influence of the process of reserving filled containers of the cotton picker on the completeness of the cotton harvest

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Abstract. The technology and technical means for collecting cotton in elastic cylindrical containers, loading them and transporting them to cotton processing enterprises have been developed, allowing to increase the productivity of the complex of machines and preserve the quality of the grown crop. The design of a cotton harvesting machine is proposed, analytical studies are carried out to ensure the stable operation of the machine mechanisms in accordance with agrotechnical requirements. It is assumed that the reserve device with the support wheel will have a damping effect on the harvesters not only in the process of reservation, but also in the process of picking cotton with a reserved container. To do this, it is necessary to conduct comparative experimental studies to determine the effect of the reserve device on the course stability and agro technical indicators of the cotton picker for wheeled and wheel less schemes of reserve devices.

1 Introduction

Scientists of the Scientific Research Institute of Agricultural Mechanization and the Karshi Engineering and Economic Institute proposed a technology for harvesting raw cotton with its compaction in elastic containers installed on a cotton picker. This technology makes it possible to completely eliminate the unloading time of the cotton picker, which eliminates the relationship between the productivity of the harvesters and the utilization rate of the shift time of the machine [1, 2].

A scheme of a reserving device for a hinged system of a cotton picker with a side arrangement of filled containers and unloading on both sides is proposed (Figure 1). In this regard, a new dynamic process appears in the operation of the cotton picker, associated with the movement of a rather significant mass of a container filled with cotton [3-5]. Therefore, it is necessary to study the influence of this process on the dynamic and related agro technical indicators of the cotton picker. According to the research, they were engaged in S Alikulov [1, 2], F Maiviatov [3, 4], S Toshtemirov [4, 5], B Mirzaev [6, 8-10], I Temirov [7], M Amonov [8], R Karimov [9, 10] and others. To do this, the amplitudes of oscillations of the machines caused by the redundancy process were determined, and then, according to the empirical dependencies given in, the expected decrease in the completeness of the collection,

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due to vertical and transverse-horizontal oscillations of the harvesting machines, was determined.

2 Materials and methods

Research is divided into three consecutive stages [6-7]:

- study of spatial oscillations of the frame of the cotton picker in the process of redundancy, as a conservative dynamic system;
- study of the dependence of forced oscillations of vehicles with serial suspension on spatial oscillations of the machine frame;
- determination of the expected decrease in the completeness of the collection as a result of oscillations of the devices.

In the process of research, the following assumptions were made: - the impact of the container on the platform of the backup device is considered inelastic; - before the start of the impact of the container, the system is in equilibrium; - the center of gravity of the container is located in its geometric center.

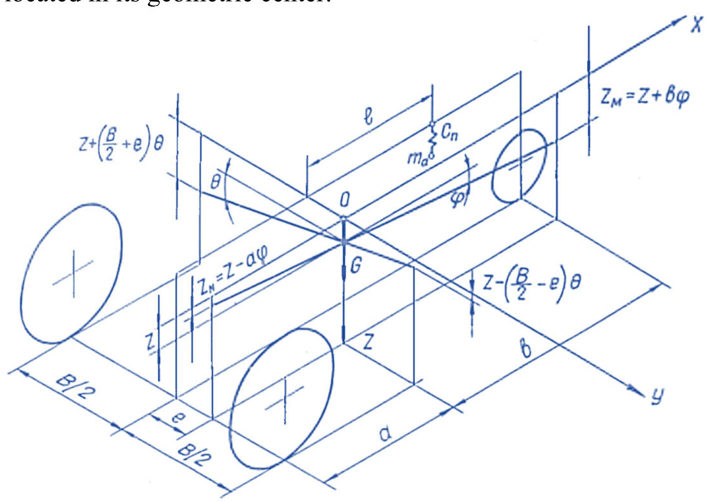

Fig. 1. Calculation scheme of vibrations of the skeleton of a cotton picker.

We will consider the physics of the redundancy process (Figure 1). When reserving, the filled container 1, which is in a vertical position on the support platform 2, is tilted by the container changer to an angle $\propto$ above the platform 3 of the reserving device, fixed on the frame 4 of the machine, is released and falls onto the platform. In the process of falling, the container acquires a certain kinetic energy of the Tr. An inelastic impact phenomenon occurs, as a result of which free oscillations of the frame of the cotton picker together with the reserved container around a common center of mass occur.

Thus, the redundancy of filled containers causes the cotton picker to oscillate due to the interaction of the kinetic energy of the container and the potential energy of the cotton picker frame. Therefore, when studying the redundancy process, the machine should be considered as a stationary conservative system with several degrees of freedom.

Like any rigid body, a machine can have six degrees of freedom: longitudinal-horizontal (x); transverse horizontal (*y*); and vertical (z) oscillations of the center of gravity, as well as angular oscillations around the center of mass: longitudinal-angular (φ) relative to the transverse axis Y; transverse-angular (θ) relative to the longitudinal axis X and angular displacement (φ) relative to the vertical axis (Z). However, at low speeds, not all possible oscillations reach significant values for the following reasons [8]

a) structurally, the frame of the cotton harvester cannot make significant longitudinal linear vibrations (x) with respect to the wheels;
b) the design of the suspension and the adhesion of the wheels to the ground do not allow significant lateral vibrations (y) of the frame;
c) the design of the cotton picker tractor ensures stable rectilinear movement without yaw of the frame, i.e. significant fluctuations around the (Z) axis are not possible.

Thus, only vertical linear (z), longitudinal-angular (φ) and transverse-angular (θ) vibrations usually reach significant values, which must be studied.

The equation of motion of a system located in a conservative force field and having s-degrees of freedom is called the Lagrange equation of the second kind for conservative systems and has the form [8]:

$$\frac{d}{dt}\left(\frac{\partial T}{\partial qj}\right) - \frac{\partial T}{\partial q} = \frac{\partial \Pi}{\partial q_j}, \ (j = 1, 2 \ldots s), \quad (1)$$

where, T – is the kinetic energy of the system; P – is the potential energy of the system; s – is the number of degrees of freedom (s = 3); q_j – is a generalized coordinate.

To find the equations of free oscillations of the system, we take as the origin of the generalized coordinates, according to the assumptions made earlier, the equilibrium position of the system, i.e. we assume that the generalized coordinates q_1, q_2 and q_3 in this position are equal to zero.

The kinetic energy T, which the system has after the inelastic impact of the container, which is included in equation (1), is determined as the total energy of the machine and the container in the corresponding coordinates

$$T = \mathrm{T} = \frac{1}{2}\sum_{i=1}^{3} \ , \ \sum_{j=1}^{3} a_{ij}\, q_i\, q_j, \ (i, j = 1, 2 \text{ and } 3), \quad (2)$$

where, a_{ij} – are the coefficients of inertia.

In our case, the impact is inelastic, and therefore we assume that the system oscillates as a whole, i.e. the mass of the container after the impact belongs to the mass of the machine.

The expression for the kinetic energy of the system has the form:

$$T = \frac{1}{2}(m + m_k)\, z^2 + \frac{1}{2}(J_x + J_{\kappa x})\, \dot{\theta}^{\,2} + \frac{1}{2}\ (Jy + J\,ky)\varphi^2, \quad (3)$$

where, m and m_k are the masses of the machine and the container; J_x and J_{kx} - the moment of inertia of the machine and the container, relative to the X axis; J_y and J_{ky} - the moment of inertia of the machine and container, relative to the Y axis.

Potential energy P will be determined by the rigidity of the tires and the amount of their deformation:

$$\Pi = C_1\frac{z_1^2}{2} + C_2\frac{z_2^2}{2} + C_2\frac{z_3^2}{2}, \quad (4)$$

where, C_1 and C_2 are the stiffness of the tires of the front and rear wheels, respectively; z_1, z_2 , z_3 - offset along the Z axis of the points located under the front, rear left and rear right wheels.

Let us express the potential energy of the system in terms of the accepted coordinates z , θ , φ.

As a result of the asymmetric arrangement of the masses of the machine and the reserved container relative to the longitudinal axis of the tractor, the center of gravity of the system is shifted by e. From Figure 1 for sufficiently small angles, we find:

$$z_N = z - a\,\varphi; \qquad Z_M = z + в\,\varphi.$$

Then, $z_1 = z_M - e\,\varphi,\quad z_2 = z_N + (B/2 + e)\,\theta,\quad z_3 = z_N - (B/2 + e)\,\theta,$

Substituting the values z_1, z_2, z_3 into equation (1), we obtain in the final form the potential energy of the system

$$P = \frac{C_1}{2}(z + b\varphi + e\theta)^2 + \frac{C_2}{2}\left[z + a\varphi + \left(\frac{B}{2} + e\right)\theta\right]^2 + \frac{C_2}{2}\left[z - a\varphi - \left(\frac{B}{2} - e\right)\theta\right]^2, \quad (5)$$

Consider the kinetic moments of the container with vertical reservation. We assume that the center of mass of the container is concentrated in its geometric center. Then, when the container falls from an inclined position to a horizontal position, the center of mass acquires a speed vy and at the moment of impact, the momentum of the container will be equal to $m_k v_y$, (Figure 2). We direct the vector $m_k v_y$ tangentially to the trajectory of the center of mass of the container. Point O – is the center of gravity of the machine, and O_1 is the point of impact of the center of mass of the container on the platform of the backup device

$$K_{ky}{}^{B} = m_k\, v_y\, d_y{}^{B} \;= m_k\, d_y{}^{B}\;\; v_x\, /\, cos\; \alpha_B\, , \tag{6}$$

where, m_k – container weight; $d_y{}^{B}$ – distance from the momentum vector to the axis Y; V_x – container speed relative to the Y axis is determined by the formula $K_{kx}{}^{B} = m_k\, V_x\, d_x{}^{B}$

To determine the momentum of the container along the Z axis, consider the vertical momentum $m_k v_x$ reduced to the center of gravity of the machine (point O, Figure 3).

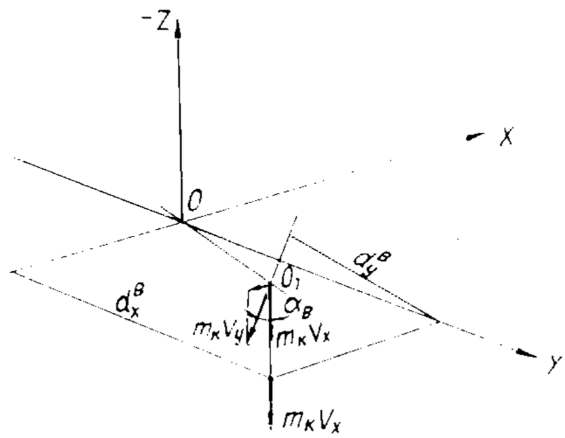

Fig. 2. Vertical redundancy then the angular momentum of the container about the Y-axis will be.

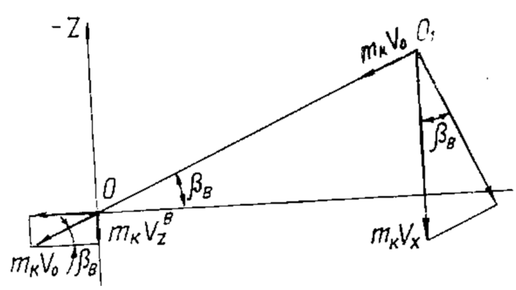

Fig. 3. Determining the momentum of the container along the Z axis.

As can be seen from Figure 3

$$m_k \;\; V_z{}^{B} = m_k \;\; V_x \;\; sin\; {}^{2}{}_{\beta B}\; , \tag{7}$$

Analyzing the formulas for calculating the inertia coefficients and stiffness coefficients [8], we come to the conclusion that the stiffness coefficients do not depend on the reservation method, but depend only on the design parameters of the cotton picker and tire stiffness.

The parameters of the stiffness coefficients for a machine with two vertical sealing chambers were determined experimentally by weighing the installation with a container located in a backup device. Then the coordinates of the center of gravity of the machines were calculated using the formulas:

$$a = L(G\; g)/(m +\; mk),\;\;\; e = B(2G3 + G_1 - G)g, \tag{8}$$

where, L – is the longitudinal base of the machine, m; B – transverse base of the machine, m; m – is the mass of the machine, kg; m_k – mass of the container, kg; G_1 – load on the front wheel, kN; G_3 – load on the right wheel, kN; a – longitudinal coordinate of the center of gravity, m; e – displacement of the center of gravity due to the design features and the mass of the container, m.

Other parameters of stiffness coefficients: $B = L - a$, m; C_1 and C_2 – stiffness of the front and rear pneumatic tires at the recommended pressure.

Taking the free spatial vibrations of the frame of the cotton picker as a perturbing factor, we determine the forced vibrations of the harvesters. Taking into account that the main decrease in the collection completeness is determined by the horizontal-transverse and vertical oscillations of the devices [10, 11], we will restrict ourselves to studying these oscillations.

Vertical vibrations of vehicles can occur due to the compliance of the hydraulic system for lifting and lowering and is determined by the coefficient of its rigidity C_P.

Transverse-horizontal oscillations of the apparatus relative to the frame, for structural reasons, cannot reach significant values, therefore, we assume that the apparatus does not oscillate relative to the frame of the cotton picker in this direction. The decisive influence of horizontal-transverse oscillations on the fullness is exerted by oscillations of the lower part of the working slot of the apparatus, which is in direct contact with the bases of cotton bushes. Therefore, the transverse-horizontal vibrations of the machines are determined by the angular vibrations of the frame of the cotton picker around the longitudinal axis X (Figure 1).

Therefore, $A_r = \rho\,\theta$, or taking into account the amplitude of free coupled oscillations of the core arising in the process of reserving the container

$$A_{g=}\rho \sum_{r=1}^{3} \mu_2^{(r)} A_1^{(r)} \sin\left(k_r t + \beta_r\right), \quad (9)$$

where, A_g - is the amplitude of the transverse-horizontal oscillations of the vehicles; ρ - polar radius from the axis to the bottom of the working gap.

From this we conclude:

– horizontal-transverse oscillations of the apparatus - the essence of the angular oscillations θ of the machine frame; - vertical oscillations of apparatus - forced oscillations of the system with one degree of freedom.

Such oscillations are described by a differential equation [8], solving which we obtain

$$A_B = \sqrt{\frac{C_П}{m_A}} \sum_{r=1}^{3} A_1^{(r)}\left(1 + e\mu_2^{(r)} + l\mu_3^{(r)}\right)\left[\frac{\sin(k_r t+\beta_r)+\sin(kt+\beta_r}{2(k_r+k)} - - \frac{\sin(k_r t+\beta_r)-\sin(kt+\beta_r}{2(k_r-k)}\right], \quad (10)$$

Equation (9) expresses the dependence of the vertical vibrations of the machines on the spatial vibrations of the frame of the cotton picker when reserving the container.

The determination of the decrease in the completeness of the collection from the oscillations of the harvesting devices was carried out according to the empirical dependencies given in [9].

$$\Delta P_g = A_y (A_G) - A_1 A_Г + A_2 A_g^2, \quad (11)$$

$$\Delta P_B = A_3 (A_B) - B_1 A_B + B_2 A_B^2$$

where, $A_1 = 0.05\%/cm$, $A_2 = 0.11\%/cm$, $B_1 = 0.1\%/cm$, $B_2 = 0.007\%/cm$ are the coefficients of the functions of reducing the completeness of the cotton harvest at 90% indicators of the completeness of the collection; A_G - the amplitude of the transverse-horizontal vibrations of the devices; A_B - is the amplitude of the vertical oscillations of the vehicles.

3 Results and discussions

The overall decrease in collection completeness is determined by summing up the reductions due to horizontal and vertical fluctuations:

$$\Delta P = \Delta P_g + \Delta P_A, \quad (12)$$

Thus, as a result of the conducted analytical studies, a decrease in the completeness of the collection was determined from the dynamic effects of the mass of the reserved container on the frame of the cotton picker, i.e. with the help of a mathematical apparatus, the path of the influence of the impact of the container on the platform of the reserving device was traced, through the dynamic system of the skeleton - suspension - devices on the completeness of the collection of the cotton picker.

Table 1 shows the results of calculations of the oscillation amplitudes of the frame and apparatus of the cotton picker depending on the mass of the reserved container and the expected decrease in the completeness of the collection. From this table it can be seen that the process of reserving the container causes significant oscillations of the harvesting machines of the cotton picker and leads to a decrease in the completeness of the collection to 2.3 - 4.4%, Therefore, it is necessary to take additional measures to reduce the amplitudes of the oscillations of the machines.

Table 1 The results of the analytical study (installation based on CNP – 1,8).

Parameter	Container weight, m_k, kg				
	250	275	300	325	350
Z, cm	3.1	3.26	4.23	4.7	5.0
θ, rad	0.014	0.016	0.019	0.021	0.023
φ, рад	0.015	0.015	0.02	0.022	0.025
A_g, cm	2.43	2.61	3.16	3.67	3.9
A_B, cm	1.1	1.15	1.5	1.67	1.79
Reducing the completeness of the collection, %	1.0	1.1	1.6	2.1	23

4 Conclusions

The process of reserving containers causes significant fluctuations in the machines of the cotton picker, which can lead to a decrease in the completeness of the collection of raw cotton by 2.3 - 4.4%. Therefore, in order to reduce the amplitude of oscillations of the devices, the reserve device should be installed on the support wheel moving along the aisle. It is assumed that the reserve device with the support wheel will have a damping effect on the harvesters not only in the process of reservation, but also in the process of picking cotton with a reserved container. To do this, it is necessary to conduct comparative experimental studies to determine the effect of the reserve device on the course stability and agro technical indicators of the cotton picker for wheeled and wheel less schemes of reserve devices.

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