ANALYSIS OF THE MASS–GEOMETRIC CHARACTERISTICS OF APRICOT PITS AND NUMERICAL DETERMINATION OF THE KINETIC PARAMETERS OF THE FRACTURING STRIKER OF A COMBINED MACHINE

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Abstract

The study determines the averaged mass–geometric characteristics of apricot pits, which assist in the development of the geometric dimensions of the fracturing working element and serve to determine the technological parameters of the fracturing working organ. The actions of the power mechanisms are mathematically modeled, and graphs of linear and angular displacements, velocities, and accelerations of various power mechanisms of the combined machine are constructed through numerical experiments.

Keywords

shell; power mechanism; kinematics; power mechanism; combined fracturing machine; fractured masses; pits; apricot; dried fruits.

Introduction. Mechanical grinding and destruction of materials can be carried out by various methods, the most common of which are: crushing, splitting, breaking, sawing, impact, abrasion, cutting, and combinations of these methods. Analysis of completed studies on static and dynamic loading of various materials shows that among all destruction methods, forced and free impact are the most effective for the majority of multicomponent structurally heterogeneous materials [1,2]. The above-mentioned methods of mechanical destruction and their combinations determine the non-uniformity of particle destruction, especially for multicomponent structurally heterogeneous materials. The unevenness of destruction is determined by differences in the physical-mechanical, biological, and chemical properties of each particle. The results of studies conducted by R. Guillot, A.R. Demidov, L.A. Glebov, V.A. Denisov, and S.V. Zolotarev [3,4] showed that grinding most multicomponent structurally heterogeneous materials using free impact makes it possible to obtain a high-quality ground product while consuming a minimal amount of energy.

The most important factor influencing the grinding–fracturing process during breaking is the limiting value of the fracturing force applied to particles of dried material. Excessive force and striker velocity lead to excessive destruction of dried fruits. The velocity of particle ejection is influenced by a number of factors: the length of the acceleration tools, the shape of the working element, and the rotational speed of the shafts. Research Methods. The study employs methods for analyzing information related to the process of fracturing the shells of nuts and small dried fruits. To formulate the systems of equations, equations were used.

Lagrange equations of the second kind. Numerical calculations of the linear and angular displacements, velocities, and accelerations of the machine's power mechanisms were carried out. Results and Discussion. Nine different apricot varieties and their pits were investigated, including: Sinchalak, Kandak, Ak Navat, Javzak, Shirin Jaupakzak, Mayskiy, Childona, Kandak Krasnyy, and Bodomcha [5,6].

For example, fruits of the Sinchalak variety are of medium size, measuring 4.7 × 4.3 cm, with a mass of 40–45 g, and have a round–oval shape with an excellent appearance. The apex of the fruit is slightly pointed, and the depression at the base is shallow. The ventral suture is shallow. The fruits are yellow with a pink blush covering up to 0.5 of the fruit surface. The skin is dense and thick and is removed from the fruit with difficulty. The cavity is uniform in color with the flesh. The flesh is yellow, cohesive, and of medium density. Juiciness, sugar content, and acidity are moderate. The taste is excellent. The variety is universal in use and is suitable for drying and transportation. It ripens at the end of May. The advantages of the variety include resistance to late spring frosts, high transportability, and good taste and market qualities.

The pit is of medium size, round in shape, and easily separates from the flesh. The average pit dimensions are: maximum pit length 19 mm; maximum pit width 18 mm; shell wall thickness 0.8 mm; shell joint width 4 mm; and mass 1.2–1.7 g. Pits of the Childona variety are suitable for the preparation of Shurdanak (salted pits).

Mass–geometric characteristics of the apricot pit

Cultivar	Maximum Stone Length, mm	Maximum Stone Width, mm	Shell Wall Thickness	Shell Seam Width	Weight, g
"Sinchalak"	19	18	0,8	4	1,2-1,7
"Kandak"	20	14	1	3	1,0-1,2
"Ak Navat"	19	15	1,2	5	0,9- 1,2
"Shirin Dzhaupazak"	21	14	1	4	1,0-1,3
"Childona"	15	13	0,7	3	0,7-0,9

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"Bodomcha"	20	28	0,8	5	1,1-1,5
"May White"	20	18	1	4	0,4-0,8
"Red Kandak"	20	17	1	4	1,0-1,2
"Dzhavzak"	20	15	1	4	0,9- 1,4
"Userneny"	19,1	17	0,9	4	0,8-1,35

"The generalized mass–geometric characteristics of the apricot pit make it possible to develop the working element and to determine the technological parameters of the fracturing working element."

Determining the limiting value of the fracturing force acting on particles of dried fruits is considered to be a complex task. In order to solve this problem, it is first necessary to determine the geometric dimensions of the object under consideration. Therefore, it is necessary to mathematically model the actions of the power mechanisms of the combined machine. We developed kinematic diagrams and formulated mathematical models of the power mechanisms of the combined fracturing machine (Fig. 1).

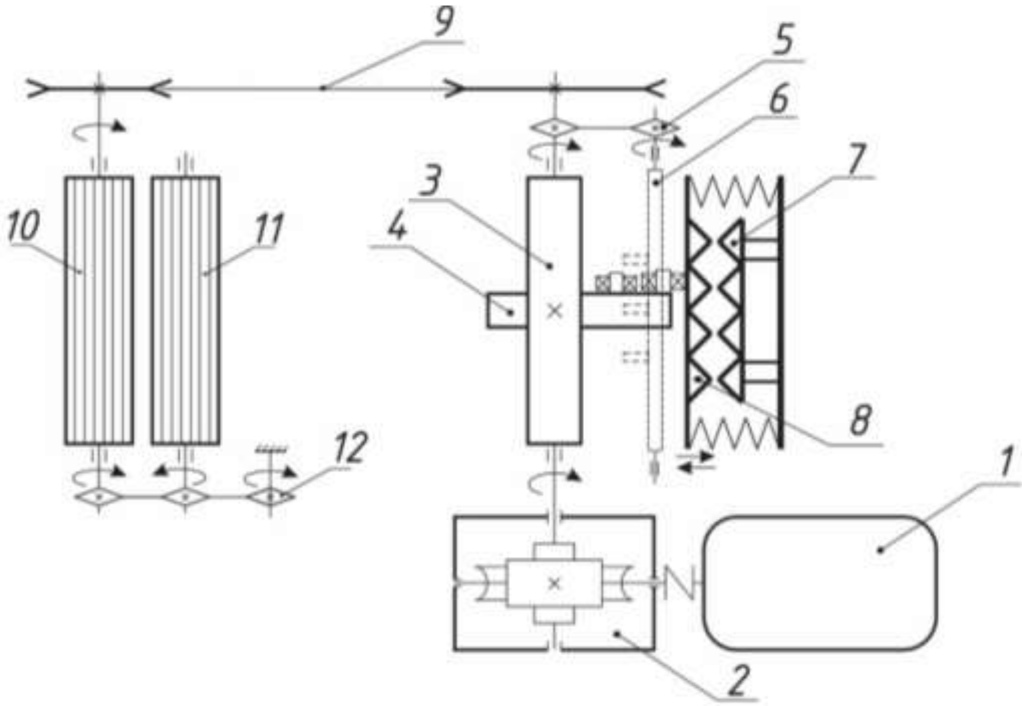

Figure 1 – Kinematic diagram of the combined machine: 1 – electric motor; 2 – worm gearbox;
3 – working shaft with cam; 4 – plate (sector); 5 – chain drive; 6 – portioning shaft; 7 – fracturing part (fixed); 8 – reciprocating fracturing striker; 9 – belt drive; 10, 11 – working shafts with grooved cells; 12 – differential chain drive.

The combined machine operates as follows. From the hopper, nuts pass one by one through a three-row guide, and the portioning shaft feeds three nuts into three cells of the fracturing chamber. In this chamber, the reciprocating fracturing striker simultaneously strikes three nuts, breaks their shells, and the fractured nuts move to the finished-product outlet. The fracturing of small dried fruits, such as almonds and apricot pits, is carried out in a separate section of the working zone. In this section, the material enters between two working shafts with grooved cells. As both shafts rotate simultaneously in opposite directions, they strike and press the dried fruits, causing the hard outer surface of the dried fruit to fracture. The fractured mass is then delivered by gravity to the finished-product outlet.

The dual-flow utilization of the motor energy (two active rotating mechanisms of the unit) in most cases increases the dynamic loading on the working shafts. Consequently, solving the problem of reducing dynamic loading in traction–drive units becomes more complex and critical than in combined units. At present, the reduction of dynamic loads in drive units by decreasing the stiffness of the drive branch, as well as the loads themselves and the mutual influence of oscillations in the traction and drive branches, have been insufficiently studied [7,8]. It is necessary to develop a mathematical model of small oscillations in the mechanisms, the distinctive feature of which is the consideration of dual-flow energy extraction from the motor under random disturbances on the driving shafts and active rotating mechanisms of the unit, as well as the consideration of disturbances caused by external effects on the driving shafts and the coupling.The machine with the calculated dynamic model of the traction–drive unit is represented by an equivalent multi-mass system shown in Fig. 2. In this case, based on the specific operating conditions of the unit, a number of simplifying assumptions are adopted: the motion of the unit occurs on a horizontal section; engagement of the gearbox–transmission and coupling is assumed; fluctuations of the angular velocity of the motor shaft occur within the insensitivity zone of the regulator.

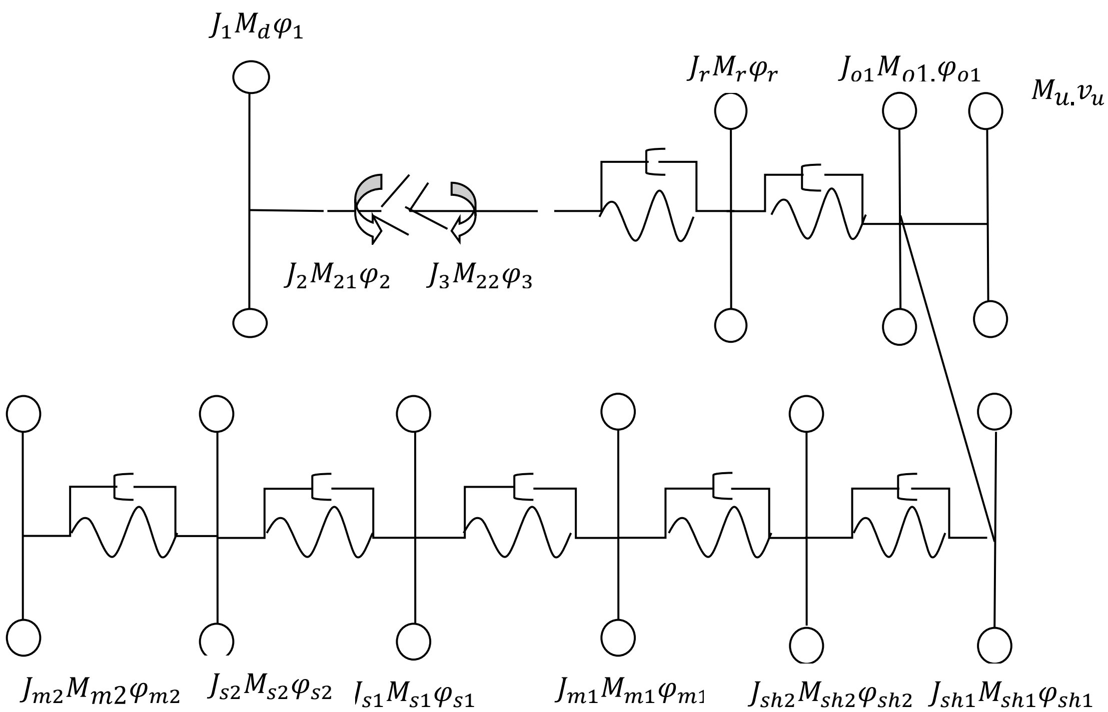

Figure 2 – Equivalent computational scheme of the drive transmissions and working elements of the combined machine.

The equations of motion of the masses of the equivalent system are written on the basis of expressions for potential and kinetic energy and the Lagrange equations of the second kind for each generalized coordinate.

$$\begin{cases} J_1\ddot{\varphi}_1 + k_1(\dot{\varphi}_1 - \dot{\varphi}_2) + c_1(\varphi_1 - \varphi_2) = M_d \\ J_2\ddot{\varphi}_2 + c_2(\varphi_1 - \varphi_2) = M_{m21} \\ J_3\ddot{\varphi}_3 + c_3(\varphi_3 - \varphi_r) = M_{m22} \\ J_r\ddot{\varphi}_r + k_r(\dot{\varphi}_3 - \dot{\varphi}_r) + c_r(\varphi_3 - \varphi_r) = M_r \\ J_{o1}\ddot{\varphi}_{o1} + k_{o1}(\dot{\varphi}_r - \dot{\varphi}_{o1}) + c_{o1}(\varphi_r - \varphi_{o1}) = M_{o1} \\ m_u \dfrac{dv_u}{dt} = \mathrm{M}_u - R_{pr} - R_o \\ J_{sh1}\ddot{\varphi}_{sh1} + k_{sh1}(\dot{\varphi}_r - \dot{\varphi}_{sh1}) + c_{sh1}(\varphi_r - \varphi_{sh1}) = M_{sh1} \\ J_{sh2}\ddot{\varphi}_{sh2} + k_{sh2}(\dot{\varphi}_{sh1} - \dot{\varphi}_{sh2}) + c_{sh2}(\varphi_{sh1} - \varphi_{sh2}) = M_{sh2} \\ J_{m1}\ddot{\varphi}_{m1} + k_{m1}(\dot{\varphi}_{sh2} - \dot{\varphi}_{m1}) + c_{m1}(\varphi_{sh2} - \varphi_{m1}) = M_{m1} \\ J_{s1}\ddot{\varphi}_{s1} + k_{s1}(\dot{\varphi}_{m1} - \dot{\varphi}_{s1}) + c_{s1}(\varphi_{m1} - \varphi_{s1}) = M_{s1} \\ J_{s2}\ddot{\varphi}_{s2} + k_{s2}(\dot{\varphi}_{m2} - \dot{\varphi}_{s2}) + c_{s2}(\varphi_{m2} - \varphi_{s2}) = M_{s2} \\ J_{m2}\ddot{\varphi}_{m2} + k_{m2}(\dot{\varphi}_{s2} - \dot{\varphi}_{m2}) + c_{m2}(\varphi_{s2} - \varphi_{m2}) = M_{m2} \end{cases}$$

where $J_1, J_2, J_3, J_r, J_{o1}, J_{sh1}, J_{sh2}, J_{m1}, J_{s1}, J_{s2}, J_{m2}$ –are the equivalent moments of inertia relative to the shaft of the rotating parts: the motor, the first and second parts of the clutch, the gearbox, the nut shaft, the first and second pulleys, the first almond shaft, the first and second chain sprockets, and the second almond shaft;

$c_1, c_2, c_3, c_r, c_{o1}, c_{sh1}, c_{sh2}, c_{m1}, c_{s1}, c_{s2}, c_{m2}$- – equivalent stiffnesses of the corresponding elements;

$k_1, k_r, k_{o1}, k_{sh1}, k_{sh2}, k_{m1}, k_{s1}, k_{s2}, k_{m2}$- damping coefficients of the corresponding elements;

$\varphi_1, \varphi_2, \varphi_3, \varphi_r, \varphi_{o1}, \varphi_{sh1}, \varphi_{sh2}, \varphi_{m1}, \varphi_{s1}, \varphi_{s2}, \varphi_{m2}$ - – angular displacements of the corresponding elements;

$M_d, M_2, M_3, M_r, M_{o1}, M_{sh1}, M_{sh2}, M_{m1}, M_{s1}, M_{s2}, M_{m2}$– – torques of the corresponding elements;

M_{m21}- – torque of the driving disc of the clutch;

m_u, v_u, M_u- – mass, velocity, and moment of the striker;

R_{pr}, R_o - – spring and nut resistance forces.

Numerical experiment of the object. The system of equations (1) is solved using the Runge–Kutta method and the Maple algorithmic program. By using the initial data, numerical calculation results are obtained, and then the corresponding graphs of linear and angular displacements, velocities, and accelerations of various mechanisms of the combined machine are constructed.

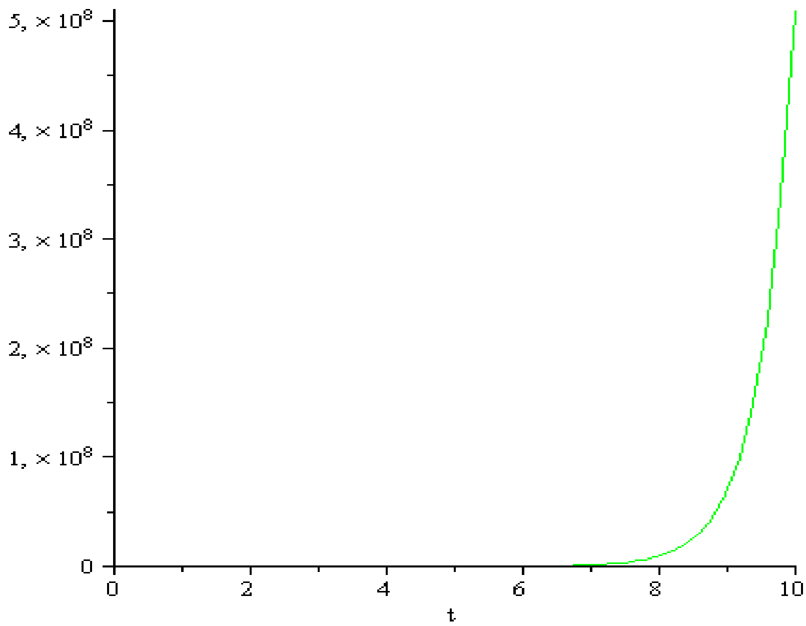

Figure 3 – Graphs of linear and angular velocities (a) and accelerations (b) of the striker of the combined machine.

The figures show the graphs of linear and angular displacements, velocities, and accelerations of various mechanisms of the combined machine. The reciprocating fracturing striker moves linearly during operation, exhibiting linear velocity and acceleration. All other mechanisms undergo rotational motion, resulting in angular displacements, velocities, and accelerations.

Conclusions. Thus, the averaged mass–geometric characteristics of the apricot pit facilitate the design of the geometric parameters of the fracturing working element and allow determination of its technological parameters. The operability of the developed mathematical model for determining the loaded power mechanisms of the combined fracturing machine for dried fruits has been substantiated. The presented graphs of linear and angular displacements, velocities, and accelerations of the various mechanisms indicate that their values are close to the real values and accurately describe the actual motion of the mechanisms.

The proposed mathematical model serves to determine the kinematic and dynamic parameters of various power mechanisms, which can be used to establish the technological parameters of the designed combined machine.

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