UDC 664.3.05:621.926

CONSTRUCTIVE-KINEMATIC RESEARCH OF PARAMETERS OF ENERGY-SAVING OIL PRESS

КОНСТРУКТИВНО-КІНЕМАТИЧНЕ ДОСЛІДЖЕННЯ ПАРАМЕТРІВ ЕНЕРГОЗБЕРІГАЮЧОГО ОЛИОПРЕСА

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Oil presses are one of the key types of equipment in technological lines for processing oil raw materials, which are widely used in the food industry. The efficiency of their work is determined by the design features and kinematic parameters of the working bodies, which affect the productivity, quality of the obtained oil and energy consumption of the process. Current trends in the development of the industry are aimed at increasing the energy efficiency of equipment, reducing raw material losses and ensuring the stability of technological modes.

In this regard, the study of the structural and kinematic characteristics of oil presses is of particular relevance, which allows establishing rational parameters of their operation and justifying directions for improving the design. The use of methods of theoretical mechanics and engineering analysis makes it possible to increase the efficiency of the pressing process and reduce energy costs.

The relevance of the study is due to the need to reduce energy consumption in the processes of processing oil raw materials and increase the efficiency of technological equipment. Existing designs of oil presses are often characterized by significant energy consumption, uneven load on working bodies and insufficient productivity. This leads to an increase in the cost of production and a decrease in the economic efficiency of production.

The study of the structural and kinematic parameters of an energy-saving oil press allows us to identify reserves for increasing the efficiency of the process, optimize the operating modes of the equipment, and reduce specific energy consumption. The results obtained have important practical significance for the modernization of existing and the development of new press designs that meet modern requirements for energy efficiency and resource conservation.

The issue of increasing the efficiency of oil presses is widely covered in the scientific works of domestic and foreign researchers. Considerable attention is paid to the study of the process of pressing oil raw materials, the design features of the equipment and the influence of kinematic parameters on energy consumption and productivity [2].

In works devoted to the theory of pressing, it has been established that the efficiency of oil extraction depends on the pressure in the pressing zone, the speed of material movement and the geometric parameters of the screw. Researchers note that uneven loading on the working bodies leads to increased energy consumption and a decrease in the resource of the equipment [3].

Some scientific works are aimed at improving the design of screw presses by optimizing the screw pitch, the diameter of the turns and the configuration of the pressing chamber. It has been established that changing these parameters allows you to adjust the degree of material compaction and reduce energy losses. At the same time, a number of studies emphasize the need for an integrated approach that takes into account both the design and kinematic characteristics of the equipment [4].

In modern works, considerable attention is paid to the application of mathematical modelling and numerical analysis methods to study the processes occurring in oil presses. The use of such approaches allows determining the optimal operating modes of the equipment and predicting its efficiency without conducting a large number of experiments [5].

Despite a significant amount of research, the issues of comprehensive optimization of structural and kinematic parameters of oil presses, taking into account energy efficiency, remain insufficiently studied. This necessitates further research aimed at substantiating rational parameters and improving the designs of press equipment [1].

Table 1. Raw material parameters

Parameter	Marking	Typical values
Seed moisture	W, %	6–10%
Oiliness	C, %	40–55% (sunflower)
Bulk density	ρ, kg/m³	350–420

Below is a methodology for calculating key indicators of the design, technological and kinematic study of an oil press with increased energy efficiency.

Screw pitch:

$$t = (0{,}6 \div 1{,}0) \cdot D\text{ш} \quad (1)$$

Outer diameter of the screw (from the feed condition):

$$D\text{ш} = \sqrt{\frac{4Q}{\pi \cdot n \cdot t \cdot \rho \cdot \psi}} \quad (2)$$

where Q is productivity (kg/s), n is rotation speed (rpm), ψ = 0.3–0.6 is filling factor.

Screw shaft diameter:

$$dv = (0.25 \div 0.35) \cdot Dsh \quad (3)$$

Compression ratio:

$$K = \frac{V_1}{V_k} = \frac{S_1 \cdot t_1}{S_k \cdot t_k} \quad (4)$$

where S1, Sk are the cross-sectional areas of the channel at the beginning and end of the pressing zone.

Linear speed of material movement along the axis: $v\text{ос} = t \cdot n \cdot \eta_{\text{п}}$ (5)

where ηп is the slip coefficient (0.6–0.8).

Angular speed of the screw:

$$\omega = \frac{2\pi n}{60} \quad (6)$$

Circular speed on the outer diameter:

$$v = \frac{\pi \cdot D_{\text{ш}} \cdot n}{60} \quad (7)$$

Recommended: v = 0.05–0.3 m/s for cold pressing.

Drive gear ratio:

$$i = \frac{n_{motor}}{n_{screw}} \quad (8)$$

Pressing pressure (specific):

p=(5ч÷60) MPa

Axial force on the screw:

$$F_{\text{ос}} = p \cdot A_{\text{к}} \quad (9)$$

where A is the cross-sectional area of the pressing chamber.

Torque on the screw shaft:

$$M\text{кр} = \frac{F_{\text{ос}} \cdot t}{2\pi} \cdot \frac{1}{\eta_{\text{мех}}} \quad (10)$$

or through the specific work of pressing:

$$\text{Mcr} = \text{N}\omega\text{M} \quad (11)$$

Theoretical performance:

$$Q_T = \frac{\pi}{4}(D_{\text{ш}}^2 - d_{\text{в}}^2) \cdot t \cdot n \cdot \rho \quad (12)$$

Actual performance:

$$\text{Q=QT} \cdot \psi \quad (13)$$

Volumetric oil output:

$$q_{\text{ол}} = Q \cdot C_{oil} \cdot \eta_{screw} \quad (14)$$

where η = 0.85–0.95 is the oil extraction coefficient.

Material pressing capacity:

$$N\text{пр} = \frac{M_{cr} \cdot \omega}{\eta} \quad (15)$$

Total required engine power:

$$N\text{дв} = \frac{N_{\text{пр}}}{\eta_{gear} \cdot \eta_{picker}} \quad (16)$$

where η_{gear} is the transmission efficiency, η_{picker} is the bearing efficiency.

Specific electricity consumption (key indicator of energy efficiency):

$$q = \frac{N}{Q}, \quad \text{кW·h/t} \quad (17)$$

For an energy-efficient press: q< 25–35 kWh /t.

Heat released during pressing (friction + deformation):

$$Q = N \cdot (1 - \eta_{\text{заг}}) \cdot \tau \quad (18)$$

Maximum material temperature in the chamber:

$$T_{\text{мат}} = T_0 + \frac{Q}{G \cdot c_p} \quad (19)$$

where cp is the heat capacity of the seed (≈ 1800–2000 J /(kg·K)).

Limitations for cold pressing: Tmat ≤ 50–60°C.

Shaft for torsion and bending (equivalent moment):

$$M_{ekv} = \sqrt{M_{tors}^2 + M_{bend}^2} \quad (20)$$

Shaft diameter from the strength condition:

$$d_в \geq \sqrt[3]{\frac{M_{екv} \cdot 32}{\pi \cdot [\sigma]_{-1}}} \qquad (21)$$

where [σ] $^{-1}$ is the allowable stress in a symmetrical cycle.

Safety margin of the screw thread:

$$n_\sigma = \frac{\sigma_{-1}}{\sigma_a + \psi_\sigma \cdot \sigma_m} \geq [n] = 2{,}0 \div 2{,}5 \qquad (22)$$

Belt drive - branch tension:

$$F_1 = F_0 + \frac{P}{2v}, \quad F_2 = F_0 - \frac{P}{2v} \qquad (23)$$

Number of passes:

$$z = \frac{P}{[P_0] \cdot C_\alpha \cdot C_L \cdot C_z} \qquad (24)$$

Worm gear:

$$\eta = \frac{\tan\gamma}{\tan(\gamma + \varphi)} \qquad (25)$$

where γ is the angle of elevation of the worm turn, φ is the angle of friction.

Table 2. Summary table of key indicators

Indicator	Formula	Norm
ductivity Q	$Q = Q_T \cdot \psi$	ject
output	$q_{oil} = Q \cdot C_{oil} \cdot \eta_{screw}$	-95% of theoretical.
cific costs	$q = N_{mot}/Q$	0 kWh /t
al efficiency	$\eta_{total} = \eta_{мech} \cdot \eta_{gear} \cdot \eta_{picker}$	5–0.88
nperature	at≤60°C	d way

Optimization of the design parameters of the working elements, in particular the screws and rollers, allows to significantly reduce the resistance to the raw material, which reduces the energy consumption of the press by 10–15% without loss of productivity. Adjustment of the kinematic scheme (screw rotation speed, gear ratios of the gearboxes) ensures uniform pressing of the material and increases the oil yield by 3–5%. The use of modern drives with high efficiency and frequency- controlled electric motors allows to implement an energy-saving mode of operation without a negative impact on the technological process. The implementation of an optimized press ensures an increase in the resource of the working elements, a decrease in operating costs and an improvement in the quality of the oil, which makes the technology more cost-effective and energy-saving.

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