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THEORETICAL ASPECTS OF THE PROCESS OF GRINDING STALK FEED CHOPPER WITH A DISK WORKING BODY

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Abstract:
This article discusses the question of mechanization of the labor-intensive process of grinding stalk feed in conditions of small forms of management. The authors propose a constructive-technological scheme of a stalk chopper chopper with a disk working body equipped with combined cutting segments. The results of theoretical studies to determine the optimal structural and technological parameters of the stalk feed chopper: productivity, energy intensity, angle of inclination of the gear grinding segment to the surface of the grinding working body, number of segments on the grinding working body, the angular velocity of the grinding working body.

Keywords: *chopper, cutting segments, performance, grinding the working body, angular velocity.*

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INTRODUCTION:

Feeding cattle with nutritious stalk feed provides high animal productivity. Stalk feed - hay, straw are the physiological need of cattle due to the structure of their gastrointestinal tract. In winter, the stalk feed in addition to other nutrients is the main feed in the diet of farm animals [12]. The composition of hay, straw includes high-grade protein, calcium, phosphorus, carotene, protein.

The share of manual labor in small farms (SF), peasant farms (PF), personal subsidiary farms (PSF) reaches 65% or more, which is due to the lack of resource-saving technical tools for performing technological operations in the production of livestock products. One of the most labor-intensive is the process of preparation and distribution of feed, which is 40% of all labor costs in farms. The use of sufficiently energy-intensive existing types of shredders, especially in conditions of SF enterprises, increases the cost of livestock production. Therefore, the development of new types of shredders with low energy intensity is an important task. One of the ways to reduce energy consumption is the use of disk working bodies equipped with combined cutting segments.

Theoretical studies of the process of grinding stalk feed with minimal energy expenditure were taken by many researchers, but such issues as grinding feed with a disk working body equipped with combined cutting segments have not been resolved. Their analysis showed that the reduction of energy costs for the grinding process is possible through the creation of new designs of the working bodies of machines [17].

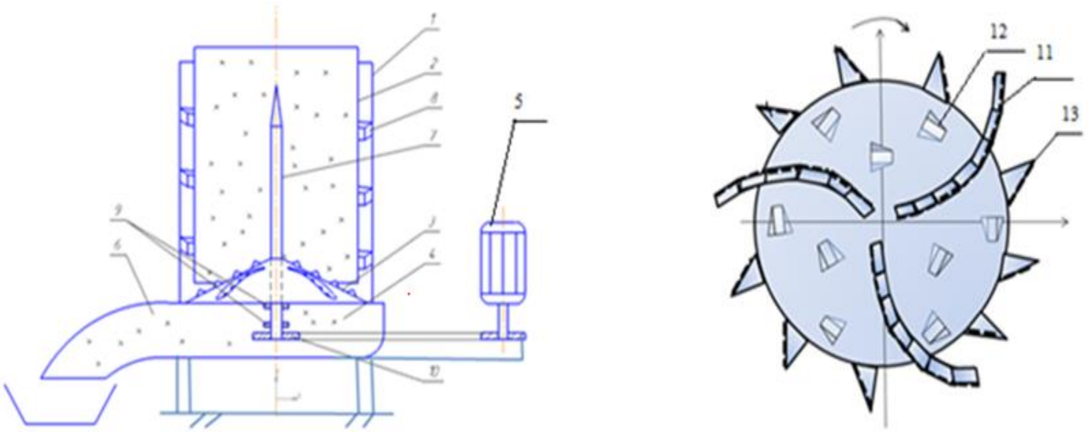
MATERIAL AND METHODS:

The analysis of existing technical means [1], [2], [3], [4], [5], on the preparation of stalk feeds involving the use of commercially available equipment, made it possible to develop a technical tool (RF patent for invention No. 2530811, No. 2542120, No. 2581488 and useful model No. 163827), which allows chopping stalk feed in a pressed form [18], [19], [20], [21].

The value of the specific energy of the process is defined as the ratio of the engine's power to the hourly performance:

$$W_{un} = \frac{N_{gr}}{Q}. \qquad (1)$$

where – Q is the chopper performance of stalk feeds, t/h; N_{gr} – power required to drive the chopper, kW.



1 - bunker, 2 - roll, 3 - grinding cone-type working member, 4,6 - duct, 5 - electric drive, 7 - needle, 8 - screw winding, 9 - bearing, 10 - pulley, 11 - horizontal gear grinding elements, 12 - crushing two-plane arc profile segments, 13 - crushing gear segments

Figure 1: Constructive-technological scheme of shredder stalk feed in extruded form

To determine the capacity of the shredder [6], [11], it is necessary to determine the area of the material cut by one segment into a transverse plane (Figure 2).

The angle of rotation of the segment on the grinding working body will be equal to:

$$\Delta\varphi = \arccos\left(\frac{\Delta s^2}{2R^2} - 1\right). \qquad (2)$$

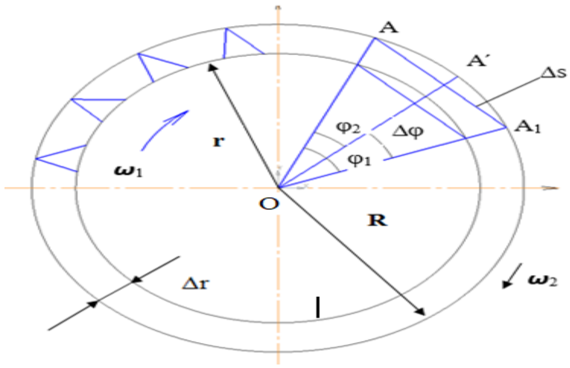
Time T impact of the segment on a roll:

$$T = \frac{\Delta\varphi}{\omega_2}. \qquad (3)$$

The conditions under which the area of the material being cut will follow one after another, so that the end of the previous area of the material being cut will be the beginning of the next, is determined:

$$\omega_{1\min} = \omega_1 \cdot \frac{\arccos\left(\Delta s^2 / 2R^2 - 1\right)}{2\pi}. \qquad (4)$$

where ω_{1min} – minimum angular speed of the grinding working body, $s^{-1.}$



R – radius of the grinding body, m; r – roll radius, m; Δr – departure of the grinding gear segments located along the perimeter of the grinding working body, m; ω_1– angle roll rotation speed, s^{-1};ω_2–angular velocity of the grinding body, s^{-1};φ_1– angle of rotation of the grinding tool with segments, deg., φ_2 – angle of roll rotation, deg.; Δφ –angle of rotation of the segment relative to the roll, deg.; Δs – segment movement relative to the roll, m.

Figure 2: Scheme for determining the parameters of the cut part of the recess

The relationship between the angular velocity of the grinding working body [7], [8], [9], [10], [13], [15] and the linear speed of the roll:

$$\frac{(1-\varepsilon)}{r} \cdot \upsilon \geq \omega_{1\min} = \omega_2 \cdot \frac{\arccos\left(\Delta s^2 / 2R^2 - 1\right)}{2\pi}. \qquad (5)$$

where υ – linear roll speed, m / s; ε – the coefficient of slippage of the roll relative to the grinding of the working body, con. un.

The area of the material being cut for one revolution of the segment is located as the area of one turn of the logarithmic spiral, which is determined by a quarter of the area of the material being cut.

The area of the material being cut off in one turn with n– number of segments on the grinding working body:

$$S_1 = \pi \cdot R^2 \cdot \frac{\Delta\varphi}{360} \cdot n. \qquad (6)$$

During the first turn, the volume of material is removed from the roll:

$$V_1 = \frac{1}{4} \cdot \pi \cdot R^2 \cdot \frac{\Delta\varphi}{360} \cdot n \cdot L \cdot \sin\alpha . \qquad (7)$$

where L – the length of the active part of the blade of the gear grinding segment, m; α – angle of inclination of the gear grinding segment to the surface of the grinding working body, degrees.

The mass of material removed for the first turn from a roll:

$$M_1 = V_1 \cdot \rho = \frac{1}{4} \cdot \pi \cdot R^2 \bullet \frac{\Delta\varphi}{360} \cdot n \cdot L \cdot \sin\alpha \cdot \rho. \qquad (8)$$

where ρ – density of the roll material, kg / m^3.

Grinder productivity, during the first turn of a roll:

$$Q^{(1)} = \frac{M_1}{T_2}.(9)$$

where T_2 – roll rotation time in the chopper bin, s.

Then the capacity of the chopper (t / h) will be determined:

$$Q = 0{,}45 \cdot R^2 \cdot n \cdot L \cdot \sin\alpha \cdot \rho \cdot \omega_2 \cdot (1-\varepsilon). \qquad (10)$$

The power required to drive the chopper is determined by the expression:

$$N = N_{xx} + N_{\text{gr}} . \ (11)$$

where N_{xx} – м the idle power needed to overcome the friction forces and other resistance forces arising during the operation of the machine, kW; N_{gr}– power required to grind material, kW.

The moment of cutting is determined by the expression:

$$M_{cut} = q \cdot L \cdot r \cdot \cos\tau \ (1 + f' tg\tau).(12)$$

where q – unit pressure of the segment, N / m; r - radius of the tangent to the plane of the knife, m; f′ – coefficient of sliding cutting; τ - slip angle, degrees.

Power for grinding is:

$$N_{gr} = \delta \cdot \frac{h}{\sin\tau} \cdot \delta_n \cdot r \cdot \omega_2 (\cos\tau)^3 (1 + f' tg\tau). \qquad (15)$$

where δ– blade sharpness thickness (20-40), micron; h - height of the removed layer, m; δ_n – normal (contact) breaking stress arising in the layer being cut, Pa.

The value of the specific energy intensity of the process can be determined from formula (1) using the expressions obtained earlier:

$$W_{un}=\frac{1{,}1\cdot\delta\cdot\frac{h}{\sin\tau}\cdot r\cdot\delta_p\cdot(\cos\tau)^3\cdot(1+f'\operatorname{tg}\tau)}{0{,}45\cdot R^2\cdot n\cdot L\cdot\sin\alpha\cdot\rho\cdot(1-\varepsilon)}. \quad (16)$$

Depending on the selected numerical values of the chopper parameters: R, (r) = 0, 28 m; n at 12 to 21 pieces; α at 30^0 to 35^0; ρ = 160 kg/m^3; τ= 300; h = 0, 02 m; L = 0, 07 m, δ_n=0,03 – 008 Mpa, ε=0,85, numerical value of the specific energy intensity varies within at 2,0 to 2,5 kWh / t.

RESULTS AND DISCUSSION:

According to the obtained expression of the specific energy intensity (16), the dependence of the specific energy intensity on the angle of inclination of the curvilinear segment to the surface of the grinding working body is constructed $\tau=30^0$ to $\alpha=40^0$ (figure 3). Rational value W_{un} equal to 2.5 kW×t/h to be at $\tau=30^0$. Then, with an increase in the angle of inclination of the curved segment to the surface of the grinding working body, the energy intensity increases to 8 kW×h/t. the Studies were carried out in this range, since these parameters in accordance with other meet the zootechnical requirements for the length of the cutting material for cattle.

According to the obtained expression of productivity (10), the dependence of productivity on the change in the angular velocity of the grinding working body ω = at 3,2 to 4,6 s^{-1} and the number of segments (figure 4 a, b).

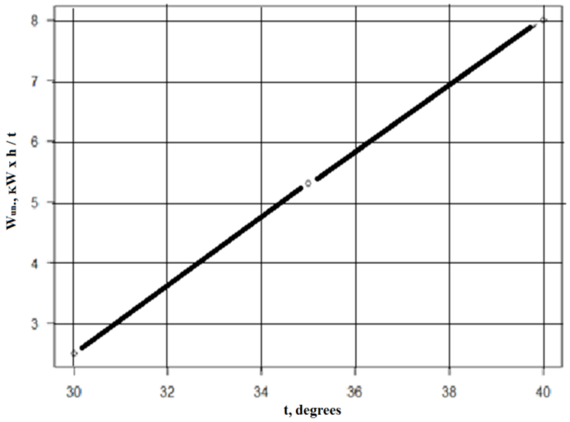
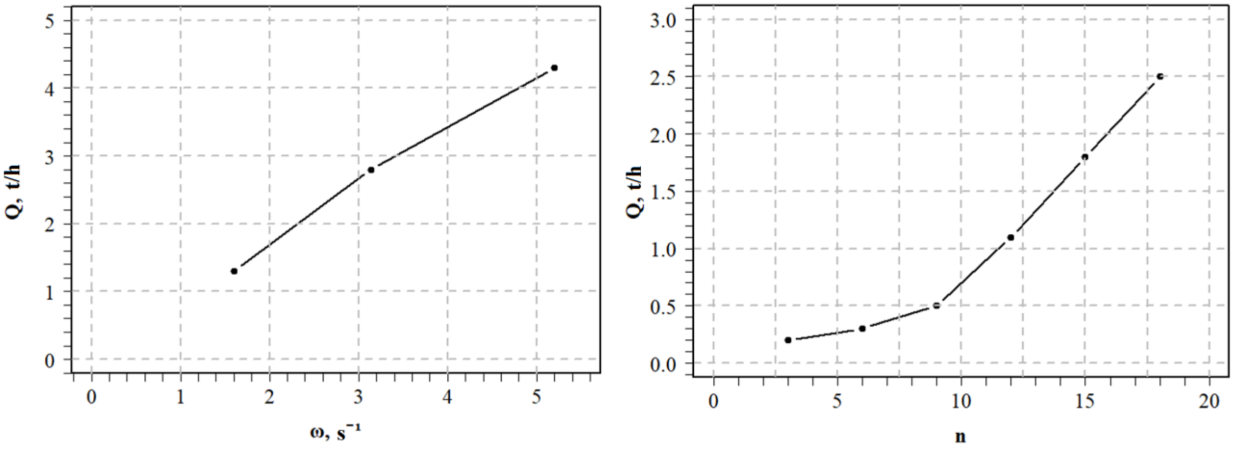


Figure 3: Diagram of the dependence of the specific energy intensity of the change in the angle of inclination of the curved segment to the surface of the grinding working body.



a) b)

Figure 4: Graph of the performance of the changes: a) angular velocity of the grinding working body; b) number of segments

CONCLUSION:

As a result of the theoretical analysis of the working process of the chopper of stalk feed [14], [16] in the compressed form, analytical expressions were determined, which allowed to determine the design and technological parameters of the chopper of stalk feed, affecting the energy intensity: the angular velocity of the grinding working body (ω); the angle of inclination between the grinding working body and horizontal toothed segments (α); the number of toothed segments located along the perimeter of the grinding working body

(Z) and the number of grinding two-plane arc profile segments (n).

Theoretical studies have established rational design and technological parameters of the combined cutting segments: the angular velocity of the grinding working body at 2,4 to 3,3 s^{-1} , при производительности равной at 2 to 3 t/h accordingly; the angle of inclination between the grinding working body and the horizontal toothed segments is at 30^0 to 32^0; the number of toothed segments located along the perimeter of the grinding working body equal to Z=9; the number of grinding two-plane arc profile segments equal to n=6.The specific energy intensity of the process ranges from 2.0 to 2.5 kWh/t.

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