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Parameters and operating modes of the working organs of the machine for harvesting forage grass seeds by comb on the root[1]

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Abstract. The results of research on the development and justification of the parameters and operating modes of the working organs of the machine for harvesting forage grass seeds are presented. Two variants of machines for harvesting forage grass seeds (stripper) were developed: a hinged stripper with a combing drum, beads from rubberized combs and a trailing comb, with a brush drum for combing grass seeds and equipped with a cutting device for cutting stems. Analytic equations characterizing the trajectory and velocity of the end of the rubberized combs of the combing drum are obtained. Analytical dependencies characterizing the conditions of capture and length of the combs are established, the coefficient of the influence of the combs on the ears of the plant stems is determined. Theoretical and experimental studies were carried out and the parameters of the working bodies of the trailer stripper equipped with a brush drum and a cutting device are justified. The production tests were carried out, the quality of the alfalfa seedbed and the power needed to drive the machines were determined.

Key words. Harvesting of alfalfa seeds, combing drum, rubberized combs, brushes, power, grain harvester, cutting device.

1. Introduction

Out of 182 million hectares of pastures of the Republic of Kazakhstan, due to unsystematic grazing, 30–40 % of pasture lands are subject to degradation. For

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the radical improvement of pastures, it is necessary to create a new grass stand by sowing high-yielding varieties of perennial and wild grasses [1–3]. To accomplish this task, seeds are needed in large quantities. The development of the country's economy provides for the transformation of the agro-industrial complex into a highly developed industry capable of providing the population with quality products. One of the main tasks in this direction is the creation of a stable fodder base for livestock, the development of which is constrained by the lack of the necessary quantity of seeds of forage grasses, especially alfalfa [4–9]. The most widespread in the conditions of Kazakhstan received a separate method. Alfalfa is mowed by harvesters (ZpRB-4.2, ZhVN-6, etc.) with the laying of the beveled mass in the roll. As the beans dry out, the rolls are picked up and threshed by conventional grain combines equipped with a PS-54-108 device. The stem mass during the harvesting period has an increased humidity (60 % or more), high yield (up to 180 c/hectare). The purpose of the work is the development and justification of the design parameters and operating modes of the machine for harvesting grass seed (alfalfa) with a root comb, which ensures a reduction in seed losses and a high-quality execution of the technological process.

2. Materials and methods

The studies were carried out using classical methods of theoretical and applied mechanics, the theory of mechanisms and machines. Justification of the parameters and operating modes of the main working organs of the machine for harvesting the seeds of forage grasses; - checking the developed machine in production conditions. Experimental studies were carried out using strain gauges. A numerical analysis of the equation of motion of a comb of a reeling drum is performed using standard programs Excel, MatCaD. The processing of the results of experimental studies used the provisions of mathematical statistics. The 80 % grain mass thus formed, consisting of free grain, seeds, under the action of inertia and air flow, moves to the screw conveyor and the inclined chamber is fed into the grinder of the combine for the window-hungry gutter and separation. The separator separates the seeds from impurities in the air stream, and enters the storage hopper. The tests showed that the stripper operation is possible at speeds up to 5.0 km/s, while the productivity of the machine with a working width of 2.7 m was 1.2 hectares/h.

3. Results

The drum combs, rotating around the horizontal axis and simultaneously moving forward with the machine, perform a complex movement with the speed $V_0 = \omega R$ and simultaneously move forward with the machine at a speed V_{m}, perform a complex movement, where ω is the angular velocity of the drum rotation in rad/s and R is the radius of the drum. The trajectory of this movement must be coordinated with the height of the arrangement of the spikes. Otherwise, the combs will not comb the plants, but will push them backwards [10]. In absolute motion, the point A of the ridge describes the cycloid curve of parameters

$$x = V_{\rm m}t + R\sin\omega t,\ \ y = (H + h) - R\cos\omega t\,. \tag{1}$$

Taking the time derivative of equation (1) and taking into account that $V_0 = R\omega$ and $\gamma = \omega\tau$, we define the projections of the speed of the point of the comb of the drum

$$\left.\begin{aligned} V_x &= V_{\rm m} + V_0\cos\omega t = V_{\rm m} + V_0\cos\varphi,\\ V_y &= V_0\sin\omega t = V_0\sin\varphi. \end{aligned}\right\} \tag{2}$$

The degree of impact of the ridge on plants is determined by the formula $\lambda = V_{\rm o}/V_{\rm m}$. The operating condition of the combing drum, i.e. the occurrence of combs in plants and their combing occurs at $\lambda > 1$, i.e., when $V_{\rm o} > V_{\rm m}$. Usually, λ is taken within the limits of $1.5\cdots1.7$. At $\lambda \geq 1.7$, combs striking the ear can thresh seeds, creating losses, and at $\lambda < 1.5$, on the contrary, the combing drum will grab few stems and most of the stalk will not be exposed to it. Compliance with these conditions is necessary, so that the speed of the combs is between 8.0 and 16.0 m/s. Figure 1 schematically shows the work of the combs of a six-barrel drum, whose axis is located on the same vertical line with the front line of the bottom of the combing body. The input of the stems between the fingers of the combs occurs in the zone $\mathrm{A_0B}$ in the sections ΔX by moving the machine, so that each comb combs the ears of those stems that occur to it on this segment.

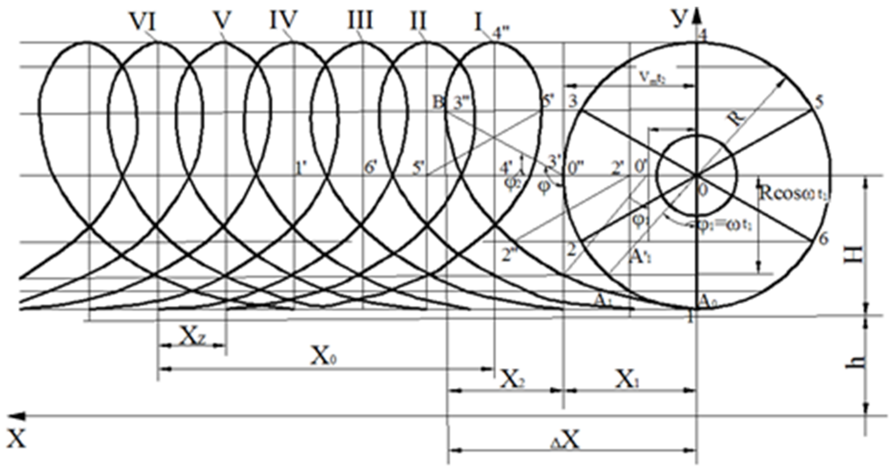

Fig. 1. Interaction of combs of combing drum with plant stems

Figure 1 shows that $\Delta X = X_1 + X_2$. On the other hand, when $0 \leq X_1 \leq V_{\rm m}t_2 = V_mt_1 + R\sin\varphi_1$, then

$$X_1 = V_{\rm m}t_2 = V_{\rm m}t_1 + R\sin\varphi_1\,, \tag{3}$$

where $\varphi_1 = \omega t_1$, so that $t_1 = \varphi_1/\omega$. When $0 \leq X_2 \leq R\cos\varphi_2$, then $X_2 = R\cos\varphi_2$

and $\Delta X = V_{\mathrm{m}} t_2 + R\cos\varphi_2$.

Taking into account that $V = R\omega/\lambda$, we finally obtain

$$\Delta X = \frac{R}{2\lambda}\left(\pi + 2\varphi_2 + 2\lambda\cos\varphi_2\right) . \tag{4}$$

On a piece of the car's path, each row of combs grabs and combs the ears of the plant stems. If the drum has Z slats with combs and for one complete revolution of the drum the machine moves to a distance X_0 equal to [10]

$$X_0 = V_{\mathrm{m}} T = V_{\mathrm{m}} \frac{2\pi}{\omega} = \frac{2\pi R}{\lambda} . \tag{5}$$

Then all Z slats with combs will sequentially capture the ears of plant stalks and comb the total length $Z\Delta X$. The coefficient of influence of the combs on the ears of the plant stalks is the ratio of the way in which the combs grab and comb the ears of the stems, to the entire path traversed by the machine during the same time

$$\eta = \frac{Z\Delta X}{X_0} = \frac{Z}{4\pi}\left(\pi + 2\varphi_2 + 2\lambda\cos\varphi_2\right) . \tag{6}$$

The step of the combing drum with slats and combs is the movement of the shaft (axis) of the combing drum X_z during the rotation time by an angle $\varphi_z = 2\pi/z$

$$X_z = \frac{X_0}{z} = \frac{2\pi R}{\lambda z} . \tag{7}$$

Usually, $\eta = 0.2 - 0.8$. To increase the coefficient of action of the combs on the stems, it is necessary to increase the number of slats Z and the value of λ. With an increase in λ from 0.3 to 2.1, the coefficient of influence η increases more than 4 times. The number of slats Z with combs was chosen from the condition of combing all the bread along the length of the rut without missing (Fig. 2), i.e., a portion, combed by combs, must strictly follow the bread combed by the previous comb.

The characteristics of harvested grasses are listed in Table 1

Table 1. Characteristics of harvested grasses

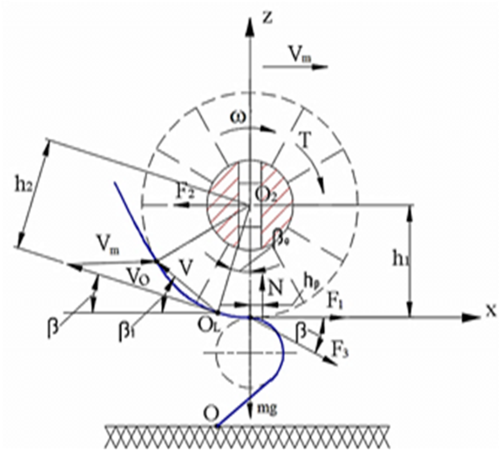

Fig. 2. Forces acting on the brush drum with its free movement in the vertical direction

Denomination	Alfalfa	Fescue meadow grass	Rangeland ryegrass	Wheat grass
Height (cm)	95,0	70. . . 75	55. . . 60	40. . . 60
Yield of seeds (c/ha)	3.0	2.5	2.5	2.65
Number of plants (t/m^2)	420.0	310.0	270	210.0
Humidity seeds (%)	18.0	11.0	12.5	14.0
Humidity of stem mass (%)	65.0	40.0	43.0	30.0

The tests showed that at a speed of rotation of the combing drum with slotted combs $n = 520$ rpm, the linear speed of the combs $V_0 = 17.96\,\mathrm{m/s}$, $V_\mathrm{m} = 1.4\,\mathrm{m/s}$, $V = V_0/V_\mathrm{m} = 12.82$, seed losses by shedding were 2.3–2.5 %, and at $n = 720$ rpm, the linear velocity of the combs $V_0 = 24.87\,\mathrm{m/s}$, $V_\mathrm{m} = 1.4\,\mathrm{m/s}$, $V = V_0/V_\mathrm{m} = 17.76$, seed loss by shedding 2.2–2.4 %, and undercuts 0.5–0.7 %. The required engine power for the drive of the combing drum was 7.2 kW. The productivity of the stripper with a width of 2.0 m was 0.8 –1.0 ha. Separation of alfalfa seeds is carried out directly on the root of the device (Fig. 2), consisting of a receiving chamber 1, mounted on it a pair of rollers: the upper brush drum 2 and lower roller 3. The power required to rotate the brush drum is determined by the formula $P_1 = P_2 + P_3$ where P_2 is the power needed to overcome friction of the brush on the stems of alfalfa, and also the breakage of the seeds is determined by the formula

$$P_2 = 4.7 \times 10^{-4} \times 736 D_2 n f_1 \cos\beta_1 F_3 \cos\epsilon\,, \tag{8}$$

where D_2 is the outer diameter of the brush along the pile (m), n is the number of revolutions of the brush drum (rpm), f_1 is the coefficient of friction of pile sliding on the surface of alfalfa stems, β_1 is the angle of the pile with a fixed shaft, $\cos\beta_1 = 1-\Delta L_0/R_2$, ΔL_0 is the amount of deformation (sagging) of the pile, R_2 is the radius of the brush drum (mm) and F_1 is the force of action of brushes on stalks of plants (N).

The gap depends also on the number of leaves and seeds to be traversed, and, consequently, the power required to break off leaves and seeds. The moment T_1, which is expended directly on the breakage of leaves and seeds from the stems, is determined by the formula (see Fig. 2)

$$T_1 = F_1 \frac{D_2}{2}\,,$$

where F_1 is the the average tearing force of one leaf from the stem (N), where $F_1 = fN$ and m is the average number of leaves terminated simultaneously in the series by a single ring of brushes. The values of F_1 and m are determined as a result of laboratory studies.

Figure 3 shows the power variation curves P_2, P_3 and P_1 as functions of the rotational speed of the brush drum. The graphs show that with increasing the rotational speed of the drum, the power is increased. With a frequency of rotation of the combing drum $n = 1000$ rpm, the power required to comb the leaves and seeds of alfalfa P_1 sharply increases to reach 5.0 kW, and the power required to overcome the air resistance to the rotation of the brush N_2 is 2.0 kW.

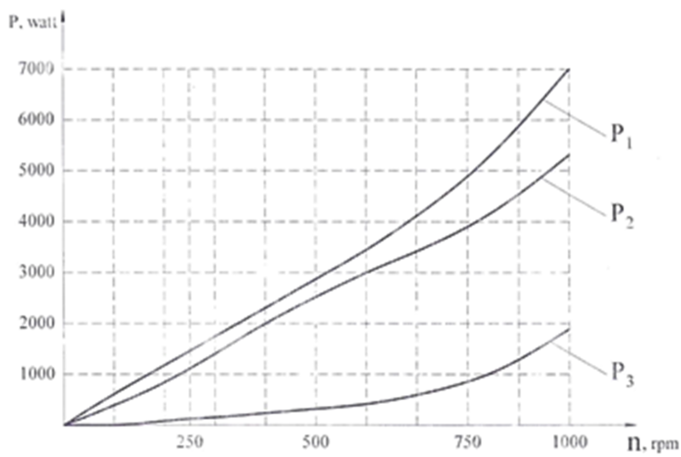

Fig. 3. Dependencies of the power P_1 required to drive a brush drum, P_2 to overcome the resistance of air to the rotation of brush and P_3 to combing of leaves and seeds of alfalfa from the rotation speed n of the brush drum

When the machine moves along the field, the combing drum combs the leaves and plant seeds, rotating downwards together with the casing and support flap, creates a suction airflow that transports them to the storage hopper. Simultaneously, a mower with a segment-finger cutting device, installed at the bottom of the pallet behind the combing drum, cuts the lower part of the stems and puts them into the wire. After filling the receiving hopper, the leaves and seeds are unloaded by means of a conveyor into vehicles. The brush drum with nylon brushes with a diameter of 2.0 mm, a length of 220 mm and a working width of 2.0 m was tested. In the experiments, the quality of the seeds and leaves collected from 100 m^2 was estimated at a brush speed of $n = 250$ and 500 rpm and different ratios of the peripheral speed V_0 of the brushes to the translational speed V_m of the machine. The power required for the drive of the universal machine of the trailer was determined by the formula: $P = T\omega = T\pi/30\,\mathrm{W}$, where T is the torque on the drive shaft (Nm), ω is the angular speed of shaft rotation (rad/s) and n is the shaft rotation speed (rpm).

Experiments have shown that with an increase in the peripheral speed of the drum 13.0–20.0 m/s, the amount of seeds and leaves collected increases, but at the same time the content of debris of stems in the heap increases. As the speed of movement increases, the loss of seed from cut plants increases from 0.2 to 2.5 %. This is due to the fact that with increasing speed of the stripper movement, the bending of the bent stems increases with the casing of the drum and the brushes do not grasp the bent stalks of the plants (Figure 4). The productivity of the machine was 1.08 ha/h. The oscillogram of the torque readings is shown in Figure 5.

Fig. 4. Combing of alfalfa seeds with a trailed universal machine

As a result of the theoretical and experimental studies of the working organs of the trailing machine for harvesting seeds and leaf mass, the parameters of the machine's working parts are justified: rotation speed: combing drum with brushes - 250–500 rpm, conveyor auger shaft $n = 410 - 540$ rpm,; crooked-spike shaft - rpm, the power required to rotate the brush drum when combing the leaf mass and seeds is determined. The best quality indices of the comb is provided at a speed of machine movement 1.0–1.5 m/s, the speed of the reeling drum is 500 rpm, and the cut quality of the stem part of the plants is ensured at a crank shaft speed of 460 rpm.

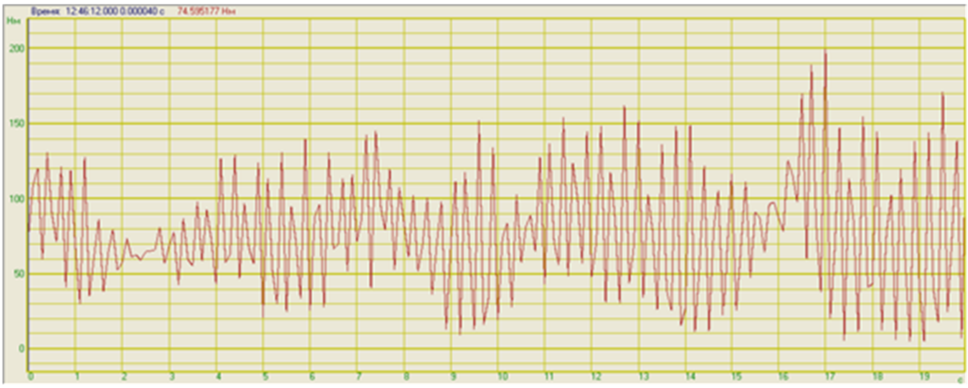

Fig. 5. Oscillogram of the sweep of the stripping device universal machine for harvesting alfalfa seeds and stamping

4. Conclusion

A promising way of harvesting grain crops, as well as testes of grasses by direct combining is to comb the grain from the ears and feed the combed mass into the combine. The parameters of the working organ of the combing drum are proved: the hinged stripper: the number of slats with the rubberized combs $z = 6$ pcs, the length of the rubberized combs $l = 220 - 240\,\text{mm}$, the distance between the lateral surfaces of the combs $t = 10 - 12\,\text{mm}$. The production test of the hinged stripper was carried out: at frequencies of rotation of a reeling drum of 520 rpm and 720 rpm. Velocity of the stripper movement is $V_{\text{m}} = 1.4\,\text{m/s}$, the degree of influence of the combs on the plants $\lambda = V_0/V_{\text{m}} = 12.82 - 17.76$, seed loss by shedding 2.2 –2.4 %, and underdosage - 0.5–0.7 %. The crushing capacity of the engine for the drive of the combing drum was 7.2 kW. The productivity of the stripper with a working width of 2.0 m was 0.8–1.0 ha. Theoretical and experimental studies were carried out on the trailing stripper and the parameters of the working bodies of the trailer stripper equipped with a brush drum and a cutting device were justified. Production tests of the combing machine were carried out during the harvesting of alfalfa seeds, the quality of alfalfa seed coat and the required power for the drive were determined. The power required to unload seed and leaf mass is 0.4 kW. The capacities required for driving the combing drum and mower with a segment-finger cutter do not exceed 12.0 kW. The productivity of the machine was 1.08 ha / h. Possible perspectives for further research is to work to reduce losses when harvesting combing grain of loose breads, grass seeds by installing stems.

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