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Rotary Haulm Chopper Parameters Development And Substantiation For Root And Tuber Crops

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Abstract

In this paper we analyzed the structures of current haulm choppers, their positive and negative aspects are determined. The dependences are derived to determine the shapes of a flexible working element line, the pulse loop and the energy required for a stem cutting off. The result of research determined the rational parameters of a haulm chopper and its experimental model was made. Also the economic effect of this design introduction was calculated.

Keywords: haulm, chopper, root and tuber crops, development, parameter, interaction, experiment.

1. INTRODUCTION.

The method of haulm removal before the harvesting root and tuber crops is important in the process of crop production. The haulm removal facilitates harvesting, contributes to a better growing of tubers, reduces the possibility of fungal and viral diseases transfer, which reduce the sensitivity of root crops to mechanical damage and the product loss during prolonged storage. [1]

There are different ways of haulm removal: with steam, flames, electric burning, etc., but they are used much less frequently than the most popular mechanical and chemical (desiccation) methods because of a high energy loss. [2]

The greatest opportunities for haulm chopper improvement depend mainly on successful solution of energy capacity reduction problem, that is, on the setting of optimal operating conditions and rational design parameters justification. In this paper we attempt to address this urgent scientific and technical problem.

In domestic practice for the mechanical removal of tops The rotary mowers and shredders like KIR-1,5 and different haulm choppers like BD are used in domestic practice for the mechanical haulm removal.

In European countries the following devices are used: RSK-2000, KS-3000, Sebeco, Structural.

The classification was developed due to the development of a large number of devices for the mechanical removal of haulm. This classification is shown by Figure 1 [3].

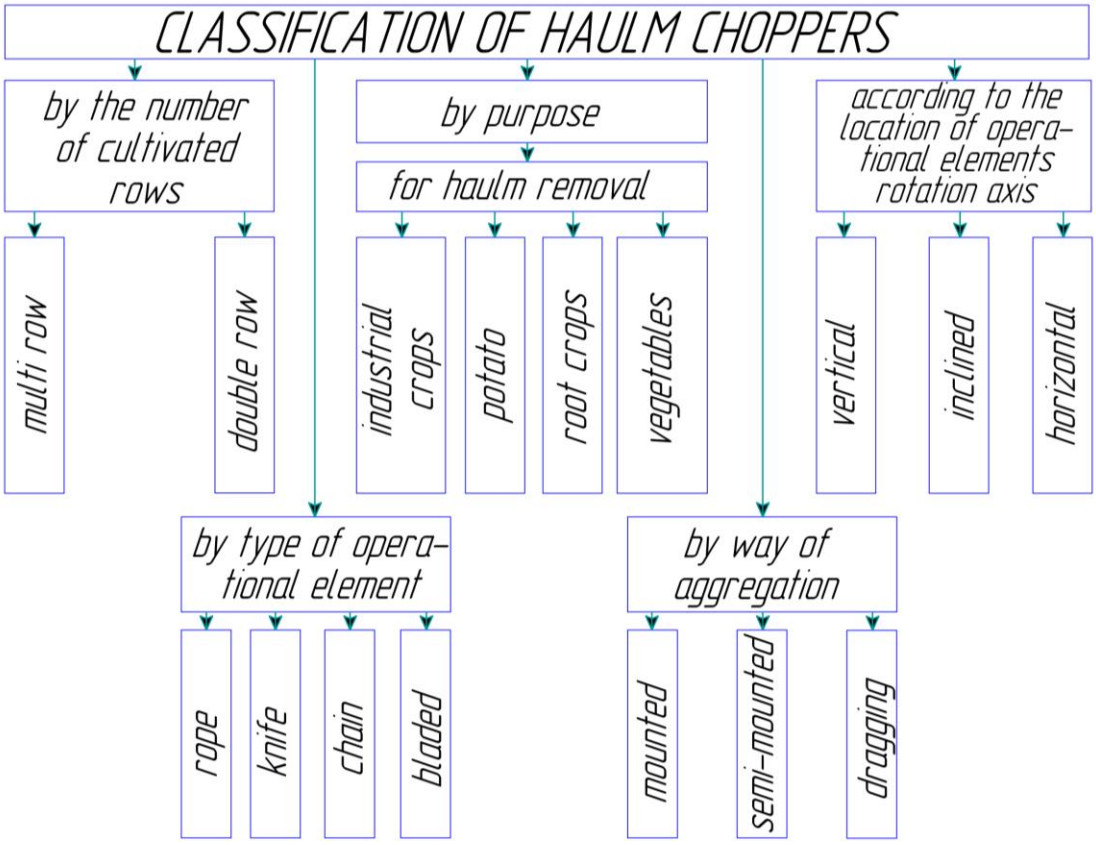


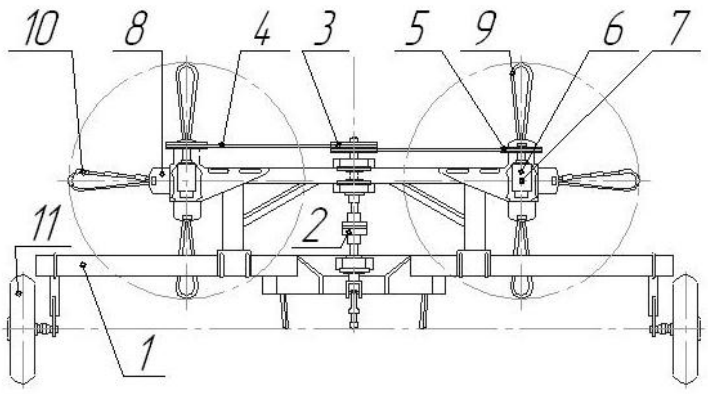
Figure 1 - Classification of devices for mechanical haulm removal.

The analysis of haulm chopper designs with rotary operational elements, as well as the study of research state in this area showed that the use of the abovementioned devices is an important way to increase the productivity, improve the quality of haulm removal, reduce the energy intensity of potato cultivation. The mechanical destruction of the Colorado potato beetle with the rotary operational elements of haulm choppers is especially important.

2. DEVELOPMENT AND SUBSTANTIATION OF ROTARY HAULM CHOPPER PARAMETERS

All current types of haulm choppers have the drawbacks in energy consumption, high cost and due to a poor quality of operation.

In this regard, we developed a four row rotary shredder of root crops haulm with the roped BIR-4, the design section of which is shown by Figure 2.



1 – frame; 2 – shaft; 3 - two-strand pulley; 4 - belt drives; 5 – gear; 7 – vertical shaft; 8 – disk rotor; 9 – flexible operational elements; 10 – case; 11 - carrier wheels.

Figure 2 – Design scheme of haulm chopper

A haulm removal (Figure 2) comprises the frame 1, mounted on a tractor mounting. The bearing frame is mounted with shaft 2. The shaft is rigidly connected to the drive double-strand pulley 3, which is connected to the driven pulley 5 through a belt transmission 4. The driven pulley is fixed of the reducer input shaft 6. The reducers of identical construction are arranged symmetrically with respect to the shaft 2 axis. The output gear shaft is fixed with the vertical shaft 7, which is rigidly set with the disk rotor 8. The flexible operating elements 9 are fixed to the rotor with bolts and buckles. The carrier wheels 11 with adjustable height are fixed on the frame. It is possible to change the height of haulm cut by these wheels.

Such a device with this form of flexible operational element allows to perform high-quality removal and grinding of root crops appropriate to agro-technical requirements.

The shape of a flexible working element line during is influenced by centrifugal forces F_{ts} (Figure 3) during rotation, the air resistance forces F_c, acting on each element dl, and also the elastic forces T, resulting during the bending of a flexible working element.

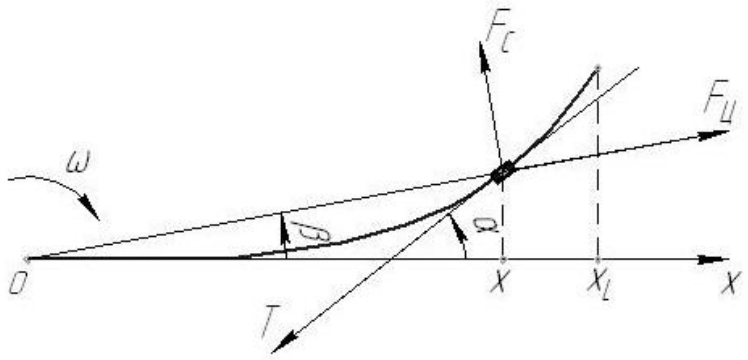


Figure 3 - The forces that influence the shape of a flexible working element line.

The formula for a flexible working element line shape was obtained on the basis of this scheme as the result of mathematical calculations and conversions

$$y(x)=\frac{1}{3}\cdot\frac{D}{\sigma*}\cdot\alpha_2 L^2\cdot\left[\left(\frac{x}{L}\right)^2+2\cdot\ln\left(1+\frac{x}{L}\right)\right]+\frac{1}{6}\cdot\frac{D}{\sigma*}\cdot\alpha_3\cdot\omega\cdot L^3\cdot\left[\left(\frac{x}{L}\right)^3+3\cdot\frac{x}{L}\right], \qquad (1)$$

where
σ – the linear rope mass density at an angle β to the axis x, kg/m;
α_2, α_3 – resistance ratios, perpendicular to dFц at each point;
D – transverse dimension of a flexible working element, m;
L – the length of a flexible working element, m;
ω – angular velocity of the flexible working element, c^{-1}.

The loop is attached to the holder at the distance l_0 from the axis of rotation (Figure 4).

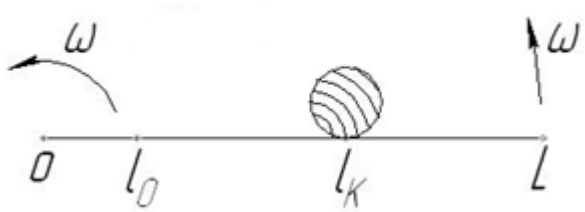


Figure 4 – Hinge mounting to the holder.

Therefore, the hinge momentum will be the following:

$$P_L=\int_{l_0}^{L}P'_l\,dl=\sigma\cdot\omega\cdot l^2\Big|_{l_0}^{L}=\sigma\cdot\omega\cdot\left(L^2-l_0^2\right), \qquad (2)$$

where *l* – the rigidly fixed length of the flexible working element, m.

In our opinion the process of a stem cutting off can not be described unambiguously. At high rotation speeds the force of impact is sufficiently high and depending on the internal structure of a stem, its humidity and other factors the stem cutting out (Figure 5а) or breaking (Figure 5и) occurs with the offset upwards (Figure 5в) at the impact area.

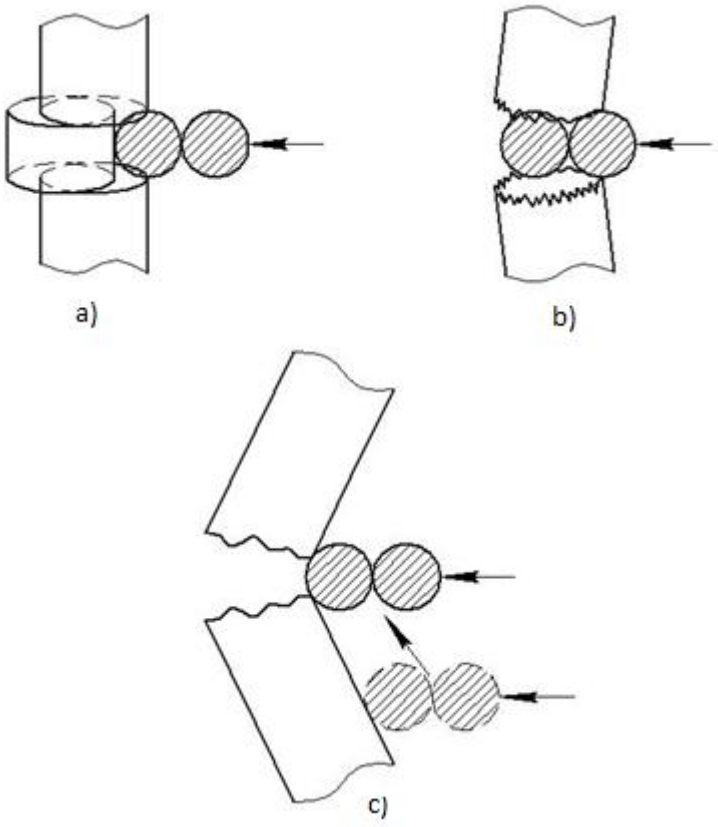


Figure 5 - Possible schemes of a loop cooperation with a stem.

The energy spent for cutting off is equal to the amount energy cutting off for each layer. Since the deformation occurs in a certain region, this energy will depend on this zone volume. It also consists of the kinetic energy from the stem flying parts. [4,5]

Combining all these forms of energy, we obtain the formula for the determination of the energy required for a stem cutting off

$$W = \alpha \cdot S + \beta \cdot S \cdot d + \frac{1}{2} \cdot \rho^2 \cdot \overline{l_K^2} \cdot \omega^2 \cdot S \cdot d = \left(\alpha + \beta \cdot d + \frac{1}{2} \cdot \rho \cdot \overline{l_K^2} \cdot \omega^2 \cdot d \right) \cdot S , \quad (3)$$

where
α - energy of a unit area stem cutting off from this material;
S – stem cross-section area, m^2;
β – the energy that is spent for the deformation of a volume unit from this material;
d – diameter of a flexible operating element, m;
ρ – material density, kg/m^2;
$l_к$ – the distance from the axis of rotor rotation to the cutting off point, m.

These equations may be used to solve practical problems of design parameters substantiation and the problems of optimal modes for rotational working elements of the cable-type haulm choppers.

Also the method of energy performance calculation was developed on the basis of OST 70.2.2-74 and the guidelines [6]. The forward speed of the aggregate is determined by a stopwatch and a tape via the measuring of the aggregate 100 m passage period with three repeats. The joint dynamometer KD-735, the operational FKP-20-200 strain sensors together with compensatory (ballast) ones are used in order to determine the torque M_{KP} on PTO. The traction resistance is determined by the information-measuring system, IP-238.

The experimental tests of the developed rope haulm chopper were conducted on the experimental field of Kazan State Agrarian University with the middle-grade potatoes "Nevsky" planted by a semi ridge method, seven days before the beginning of harvesting.

The experimental sample of the rope haulm chopper was aggregated with the tractor MTZ-82. The drive of working elements was carried out from the tractor PTO.

During the experiment the rotation speed ranged from 540 to 1500 min^{-1}, the forward one ranged from 2.5 to 4.3 m/s.

3. RESULTS.

The research established that the rational geometrical parameters of the working bodies are: the the length of a working body cable extension - 700mm, the rope diameter - 8mm, the number of blades in the disk rotor - 4.

According to the results of experiments the rational modes of haulm chopper were chosen providing the stubble height of 0.06 m, the length of chopped particles at 0.009 m, the haulm removal completeness made 98.2%, the Colorado potato beetle destruction made 94.7%: the speed of a working body made 1500 min-1, the operating speed of the aggregate made 3.5 m/s.

4. CONCLUSION.

Finally it is worth noting that the process of haulm removal is at the same high level as foreign devices but the cost of our development is much less than "foreign devices". The maintenance and repair of our device is cost effective, and the annual economic effect of applying the proposed haulm chopper makes 2600 rubles per hectare.

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