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METHODOLOGICAL CONCEPTS OF A DEFINITION OF RATIONAL PARAMETERS OF THE BRUSH-SCREW STONE SEPARATOR ON THE ELEVATOR-TYPE POTATO COMBINE

Summary

In this article a set of methodological concepts of a choice of design and parameters regime for the brush-screw stone separator in a universal modular construction potato combine of the elevator-type has been presented. The research has aimed at a realization of the principle of multi-functionality with reference to AWB, that can provide an improvement in the quality of potato cleaning as a whole and the universality of the developed machine.

OKREŚLENIE PARAMETRÓW SZCZOTKOWO-ŚLIMAKOWEGO OCZYSZCZACZA SEPARATORA MIESZANINY TECHNOLOGICZNEJ W MASZYNACH DO ZBIORU ZIEMNIAKÓW

Streszczenie

W publikacji określono zakresy parametrów szczotkowo-ślimakowego oczyszczacza separatora mieszaniny technologicznej w maszynach do zbioru ziemniaków. Przedstawiono ich wpływ na skuteczność i jakość separacji.

1. Introduction

At the creation of a universal elevator-type potato combine of modular construction a brush-screw stone separator is applied. The use of such active working body (AWB) has allowed to raise the efficiency of branch potato from stones and to lower their damageability at an interaction with it (Furletow, 1981; Ito et al., 1994).

In the design of the developed harvest unit the principle of an openness to development has been applied, which is ensured by the fast change of AWB without affecting transmission parts and with an easy alteration of the constructive structure of the unit in operation (Lisowski, 1998; Pietrow, 1984; Tanas 2001).

The use of the brush-screw stone separator has allowed to realize in one simple AWB some of the important functions: to separate a potato from large firm inclusions and to move the potato without damages to the edge of the finger hills. It is one of the many examples of realization of the principle of multi-functionality with reference to AWB, that has provided an improvement in the quality of potato cleaning as a whole and the universality of the developed machine (White and Dawson, 1991; Zaltzman and Schmilovitch, 1986).

The choice of parameters of the brush-screw stone separator represents a certain problem in connection with an absence of researches of its working process and the appropriate design procedure. The analysis of the work of such AWB therefore is of interest, with the purpose of the discovery of its laws and the development of methodological concepts for the choice of rational parameters of such a working body.

2. Key parameters of the brush-screw stone separator

The basic design data concerning the screw: radius of a coil, radius of a shaft, a step and number of coils, length of screw, thickness of coil pile.

The mode of the screw operation is characterized by the angular speed or frequency of rotation, speed of axial moving of a material, a degree of filling intra-flight spaces at work (see Fig. 1).

Power perfection is characterized by the screw efficiency, and the basic target parameter is productivity. For the definition of the productivity of the brush-screw stone separator the method of the analysis of dimension (Furletow, 1981) is used according to which the physical dependence of productivity on the screw size and the determination of sizes have been presented as a sedate complex. On the basis of the latter the equation of dimensions has been worked out from which the system of algebraic equations concerning the unknown parameters of degrees has been obtained and having defined its value, the final expression has been written down (2).

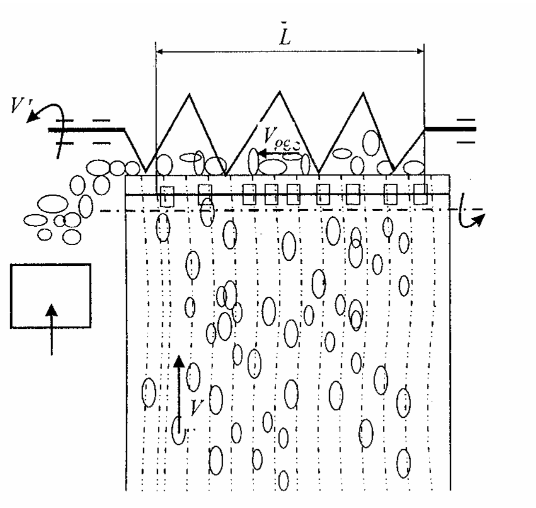

Fig. 1. The circuit of moving of a material at the work of the brush-screw stone separator

The basic regime parameter of the brush-screw stone separator is the frequency of the rotation screw. Usually it is defined proceeding from the productivity which should be provided by AWB (Feller et al., 1987 and Furletow, 1981).

The quantity of potatoes which are submitted by the finger hill to the brush-screw may be defined from the equation:

$$Q_{kl} = 0{,}1\ i\ c\ G_{kl}\ V_m,\ \text{kg/s}, \qquad (1)$$

where:
$i = 2$ – quantity of rows dug out,
c – width between two rows, m,
G_{kl} – a crop of a potato, t/hectare,
V_m – working speed of a combine, m/sec.

At a choice of a set of constructive and regime parameters it is required to achieve a rationally working screw of the maximum efficiency, so that the productivity per unit of the spent capacity (on a drive) is the optimum one. Essential changeability of operating conditions of the harvest unit strongly complicates an achievement of the optimum characteristics of a screw's working process, therefore the choice of the screw parameters is based on average characteristic parameters of conditions of operation.

The mass productivity of the brush-screw is defined from the expression:

$$Q = 0{,}5 \cdot z \cdot \square \cdot \square H - \square \cdot (1 - k^2) \cdot R^2 \cdot \square \cdot k_{\square} \cdot \square_{\square} \qquad (2)$$

where:
$\varphi < 1$ – factor taking into account the rotation of a material together with a rotor,
w – angular speed of screw, rad/sec,
R –screw radius on the edge of a coil, m,
r – radius of a screw shaft, m,
$k = r/R$,
z – number of coils screw,
H – a step of a coil, m,
□– thickness of pile in a coil, m,
y – factor of filling screw with material,
rj – density of material, kg/m^3,
$k_{\square}$ – the factor taking into account the reduction of productivity at the rise of the target end of screw on a corner β.

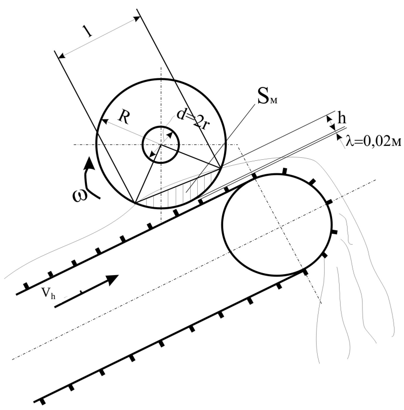

Fig. 2. The circuit of definition of parameters of the brush-screw stone separator

Let's define(determine) factor □̃

$$S_M = 1/(2[R \cdot l_\delta - l\,(r - h)]); \quad l = 2 \cdot \sqrt{h(2 \cdot R - h)},$$

where:
l_δ length of an screw arc (see Fig. 2).

$$l_\delta \approx \sqrt{l^2 + \frac{16}{3} \cdot h^2};$$

$$S_M = \frac{1}{2}[R \cdot \sqrt{l^2 + \frac{16}{3} \cdot h^2} - l(R-h)];$$

$$S_M == \frac{1}{2}[R \cdot 2\sqrt{4 \cdot h(2R-h) + \frac{16}{3} \cdot h^2} - 2 \cdot \sqrt{h(2R-h)} \cdot (R-h)];$$

$$\Psi = \frac{S_м}{S} = \frac{S_м}{\Pi(R^2 - r^2)} = \frac{0.5R\sqrt{4h(2R-h) + \frac{16}{3}h^2} - \sqrt{h(2R-h)} \cdot (R-h)}{\Pi(R^2 - r^2)} = \qquad (3)$$

$$= \frac{R \cdot \sqrt{h(2R-h) + 1{,}33h^2} - \sqrt{h(2R-h)} \cdot (R-h)}{R^2(1-k^2)}$$

Productivity of the brush-screw should provide moving of all potatoes on the sorting mountain, therefore at the constant design data the speed of the screw rotation should not be smaller than:

$$\omega \geq \frac{Q_M}{0{,}5 \cdot z \cdot \varphi \cdot (H\text{-}\delta)(1-k^2) \cdot R^2 \cdot \varphi \cdot k_\beta \cdot \rho_м}$$

The size h in expressions for □, at a constant arrangement of a trajectory of end faces of pile being relative to the finger hills at a point of their closest approach ($\Delta = \lambda$ in Fig. 2), is defined as a difference of an average thickness of the material submitted by a hill and sizes Δ.

The volume of material Q_M which has reached up to screw before contact with the pile is equal to:

$$Q_M \geq S_r \cdot h_p \cdot V_M \cdot K_n,$$

where:
K_n – the part material's digging share which has reached up to screw, applied on the data (Feller et al. 1987);
S_r – breadth of capture, m;
H_p – depth undermining, m;
V_M – speed of the unit, m/s.

Let's substitute average values, characteristic for the developed combine, and we shall receive:

$Q_{M0} \geq 1.4 \cdot 0.23 \cdot 1.5 \cdot 0.4 = 0.1932 = 0.2$ m^3/s

At bulk density potato $\rho_M = 0.65$ t/m^3

$Q_M = 0.2 \cdot 650 = 130$ kg/s

At width finger hills $S_2 = 1.26$ m and in view of an assumption about uniform thickness of a material on its width we determine values h_{max} (at $\Delta = 0.02$ m):

$$h_{max} = \frac{Q_м}{S_2 \cdot V_м} - \Delta = \frac{0.23}{1.26 \cdot 1.65} - 0.02 = 0.076 \text{ m} = 7.6 \text{ cm}$$

$\approx$ 7.5 cm.

Thus, knowing the value h, from expression (3) the value ψ for any changes of R and r researched of the brush-screw is defined.

For the maintenance of a coordination of material balance of the unit and maintenance of required stocks on the productivity as well as time fluctuations of productivity necessary for overcoming the previous working bodies, the step of a coil is accepted equal to H = 0.2 m.

One of the important parameters of the brush-screw is the number of coils and thickness of a pile in a coil. At a known length of screw and a step, the number of coils is defined from the expression:

$$I = \frac{L}{H} = \frac{1.4}{0.2} = 7$$

Thickness of pile in a coil screw is accepted from a condition unbent by stones of pile and their passage forward together with cloth finger hills: δ = 0.03 m.

Axial speed of the material which is swept away by the screw is defined by frequency of rotation and step of a coil:

$$V_{oc} = H \cdot \omega \cdot K_c = 0.2 \cdot 129 \cdot 0.8 = 0.344 \text{ m/s},$$

where:
K_c – the factor which is taking into account sliding of a material concerning the surface of a coil from pile.

Some researches of rigid screws (Ito et al, 1994) have proved that the maximum of efficiency is reached at the relation:

$$\frac{H}{R} = \frac{4}{3} = \frac{1}{3} = 1.33 \cdot$$

In connection with the features of work of a deformable pile, coil screw values H in limits from 0.15 up to 0.225 m were investigated, which correspond to a variation of relation H/R in limits from 1.15 up to 1.73 (see Tab. 1).

As the greatest possible layer of the material reaching up to the brush-screw does not exceed size h = 0.075 m, R should be more than this size, then $\psi_{max} \leq 0.4$ in view of the diameter of a shaft worm. Therefore at researches (using the program MS Excell) values R varied in limits from 0.1 m up to 0.22 m.

To pass stones under a pile it is possible to provide an effect of a variation of combinations of length and thickness of a layer, rigidity and speed of interaction of strings of a pile with the submitted material.

At unchanged diameter of strings at interaction with a material it is possible to provide the necessary rigidity and an angular deviation of pile as well as the appropriate thickness of the brush-screw stone separator pile and length of strings.

In Table 1 the exemplary results of multiple calculations parameters and the parameters of the process of the brush-screw stone separator, executed with the help of programmed spreadsheets are shown.

Table 1. Performance data of the brush-screw stone separator

Variant	z	φ	ω	H	δ	k	R	ψ	K_β	ρ_M	Q
1	1.00	1.00	15.0	0.20	0.03	0.300	0.050	0.2	1.0	0.65	0.377081
2	1.00	1.00	15.0	0.20	0.03	0.200	0.075	0.2	1.0	0.65	0.89505
3	1.00	1.00	15.0	0.20	0.03	0.150	0.100	0.2	1.0	0.65	1.620206
4	1.00	1.00	15.0	0.20	0.03	0.120	0.125	0.2	1.0	0.65	2.55255
5	1.00	1.00	15.0	0.20	0.03	0.100	0.150	0.2	1.0	0.65	3.692081
6	1.00	1.00	15.0	0.20	0.03	0.086	0.175	0.2	1.0	0.65	5.0388
7	1.00	1.00	15.0	0.20	0.03	0.075	0.200	0.2	1.0	0.65	6.592706

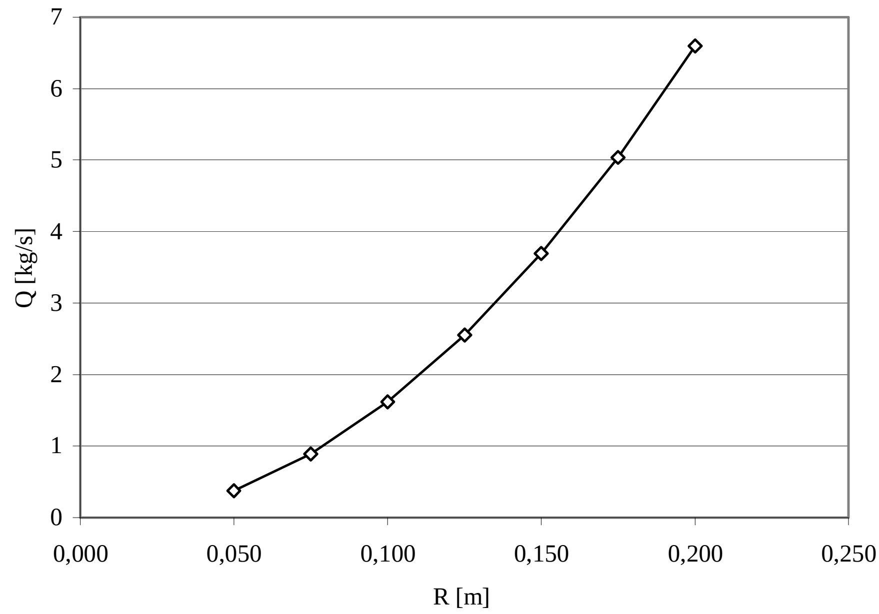

Fig. 3. Diagram $Q = f(R)$

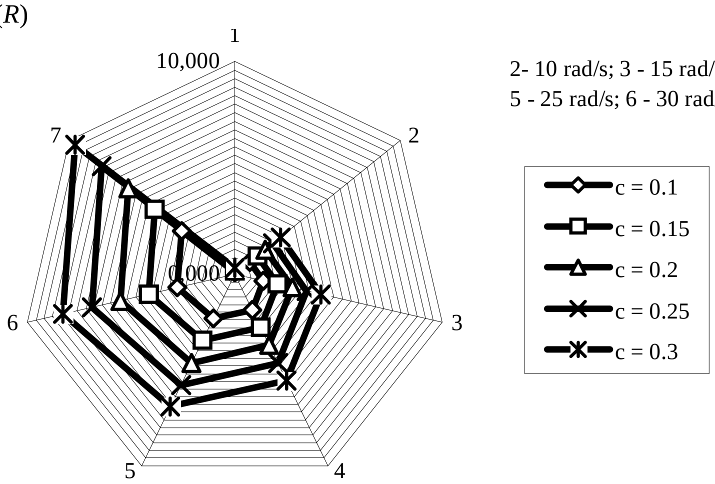

Fig. 4. Diagram Q = f(□ω), [Q] – kg/s, [ω] – rad/s. 2 – ω =10; 3 – ω =15; 4 – ω =20; 5 – ω =25; 6 – ω =30; 7 – ω =35. (In the Figure the letter c designates factor □)

On graphic diagrams, which are reconstructed automatically at change of numerical values of the initial data in spreadsheets (see Fig. 3, 4), results of the parametrical analysis of the work of the brush-screw are shown.

The received tables and graphic diagrams allow to carry out the fast and evident parametrical analysis of the work of the brush-screw stone separator at a choice of its expedient design parameters.

By the development of constructive decisions it is initially necessary to pursue the purpose – to provide a wide range operative tuning AWB of the elevator-type potato combine for the groups of characteristic conditions of operation. The last one is achieved by the creation of functional parts of the combine with opportunities of the regulation of parameters determining the working process.

3. Conclusions

As experience has shown, the offered methodological concepts of a choice of design and regime parameters for the brush-screw stone separator allow for the creation of a design and the natural industrial tests of a harvest combine. It is essential, however, to reduce the time of development and to define the necessary law for the regulation of the screw parameters regime as to the speed of movement, productivity, the condition and contamination of ground stones.

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