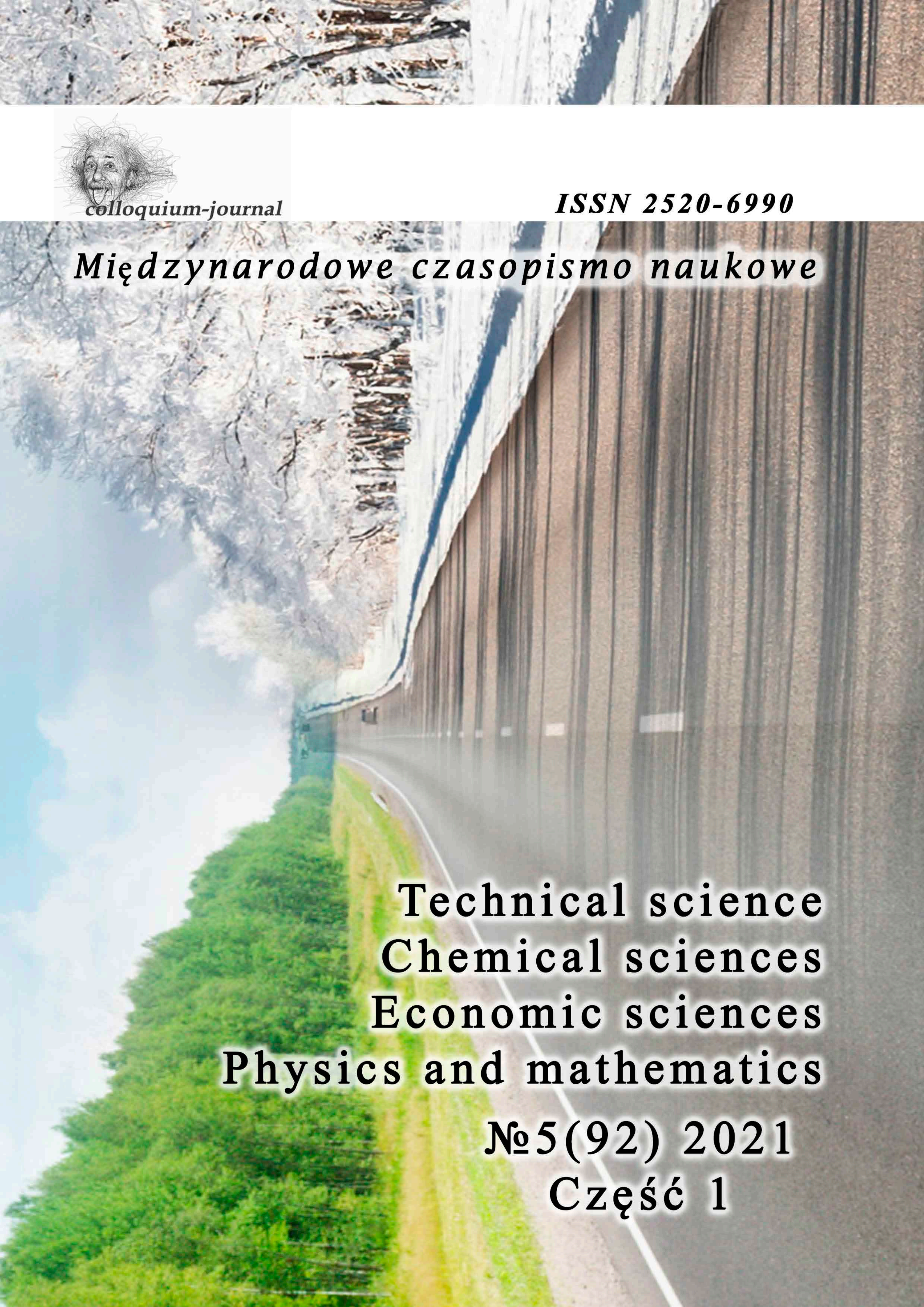

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SELECTION OF FEEDING CHANNEL PARAMETERS OF BITTER-KNIFE SHREDDING MACHINE

Abstract.

The present article deals with the selection of parameters of the feeding channel of the biter-knife shredding machine, by adjusting the cross-sectional area of the receiving neck, taking into account the throughput of the forage harvester. The dependences which allow to define the minimum equation of height of cross section of the feeding channel, length of rotor's fingers and productivity of the shredding machine are given.

Keywords: *feeding channel, shredding machine, cross-sectional area, receiving neck, rotor, throughput.*

Problem statement. Providing livestock farms with sufficient amount of fodder is a prerequisite for efficient management of agricultural enterprises. No less important is the improvement of feed quality, which affects the productivity of animals and the quality of livestock products.

Analysis of researches and publications. The analysis of researches shows that the main reserve for increasing feed production and improving feed quality is the use of new high-performance forage harvesters. Unfortunately, such forage harvesters are not manufactured in Ukraine. Currently, a КПІ-2,4 trailed combine, Марал-125 self-propelled combines of various modifications are used in Ukraine. They do not meet the current requirements for grain grinding in the harvesting of corn wax ripeness, so they are used mainly for harvesting feed for farm livestock in summer. Forage, especially corn silage, is harvested by powerful forage harvesters made in Germany, Belarus, Russia, and the USA.

It is known that when the forage harvester performs the technological process up to 80% of power consumption falls on the shredder. The shredding machine is the main and rather energy consuming [1, 2] working unit of the forage harvester. Its design determines the technological scheme of the combine and the location of the main components.

Two types of shredding machines are used in forage harvesters - drum (cylindrical) and disk. Simultaneously with cutting, they perform the function of mass transportation. These are precision cutting devices, as there is a dependence between the feed rate of the feed rollers and the length of the cut.

A fundamental work on forage harvesters, which sets out the history of the forage harvester and the theory of the process of working bodies are the monographs by Reznik N.E [3, 4]. Also, the basics of the theory of processes performed by forage harvesters are set out in the works of other researchers [5, 6, 7, 8].

It should be mentioned that when using forage harvesters in harvesting technologies, such as haylage, the authors [9, 10] point out that at least 6% of green mass is lost. These losses are caused by blowing of light fractions (leaves, buds and inflorescences) by air while loading of mass and during its transportation (losses can reach 15 - 20% if the mass is dried). Preserving this sheet mass is extremely important both to achieve the desired mass compaction in the trench or film sleeve, and for optimal dry matter and protein content. Even 10% of alfalfa losses mean lost of 3.5 tons of milk per 1 ha per year [9].

Along with forage harvesters with shredders and throwing machines, bitters and knife cutters are used, which are equipped with balers (roll and bale) and pick-up trucks. Their difference in comparison with the shredding machines of forage harvesters is the lower cutting speed and mass flow by pushing, rather than pneumatic throwing [10].

Therefore, the development and improvement of existing shredding machines of feed harvesting machines in the direction of increasing throughput, reducing the energy consumption of the cutting process and improving the quality of the feed, are always important.

Formulation of the goals of the article. The aim of the work is to select the parameters of the feeding channel of the biter-knife shredding machine with active disc knives by adjusting the cross-sectional area of the receiving neck, taking into account the throughput of the forage harvester.

Presentation of the main research material. It is possible to increase the quality indicators of stalk forages owing to the use in technological process of preparation of the last pick-up trucks and balers of such known foreign firms as: Pottinger (Austria), Mengele, Taarup (Denmark), Far, Claas, Krone, DeutzFahr (Germany), NewHolland , Case, JohnDeere (USA) and others. This is achieved due to the fact that all light fractions (leaves, buds and inflorescences) in the process of picking, pulling and loading into the body of the pick-up trucks or baler chamber, are practically not lost, but remain in the bulk, because the maximum speed 4 - 8 m / s occurs without the use of air flows in a closed channel.

The defining unit of balers pick-up trucks of machines is the shredding device of sliding cutting which feeding device, in most cases, is made in the form of a rotor [11]. A design feature of such bither-knife cutting machines is that the cutting pairs, namely, the finger of the feed rotor - a disk knife are located in the forming channel. Such devices with a rotary feeding device of foreign balers and pick-up trucks are generally placed close to each other and differ only in the design features of units and working bodies. Thus, their rotary feeder differs in the length and diameter of the drum, the number of rows and the design of the fingers (finger length and the shape of the line of the working surface), the method of attachment to the drum [11].

It is known that the productivity of the forage harvester depends on its throughput (kg / s) and the type of shredding stem material. It is clear that the capacity depends directly on the size (cross section) of the receiving neck of the shredding machine of the combine. Therefore, in modern combines, the cross-sectional area of the receiving neck is 1300-1450 cm2, which also allows you to implement the power of the engine installed on the combine [12].

The choice of the parameters of the feeding channel of the bitter-knife shredder, namely, its height and width should be made in such a way as to ensure maximum throughput. From the analysis of the cutting process and analytical dependences [1, 3, 5, 6] it can be noted that the throughput is directly proportional to the cross section, and the energy consumption of grinding is inversely proportional to the height of the transverse forming channel (thickness of the cut layer). Therefore, the choice of height and width of the forming channel of the bitter-knife device is expedient from the point of view of taking into account the power and energy indicators of the process.

The width $a_к$ and the height $b_к$ of the channel (Fig. 1) are interdependent and determine its cross-sectional area $S_к$. As the width of the channel $a_к$ increases, the height $b_к$ can be reduced and vice versa.

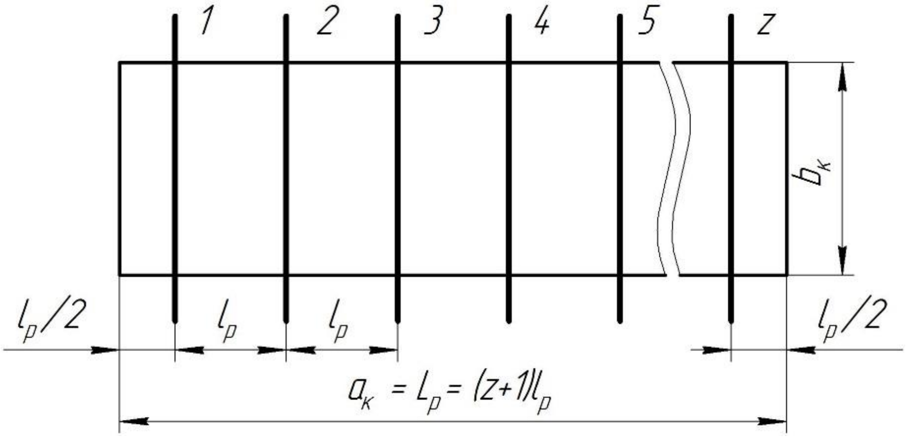

Fig. 1. Scheme for determining the cross-sectional area of the forming channel of the shredding device

Given that the proposed bitter-knife shredder is installed in the feeding channel of the balers or pick-up trucks after the drum finger picker, it can be stated that the width of the feeding channel will be equal to the working length of the finger picker or will be slightly less than that, namely $a_к \leq L_p$. From the analysis of baler designs [11] it is known that the working length of the feed rotor is proportional to the size of the chamber into which the mass is fed and for balers varies within 0.80… 1.20 m, and for pick-up trucks - within 1.45 … 1.84 m.

The height of the feeding channel $b_к$ must be taken into account the capacity of the shredding device. The minimum cross-sectional height $b_{к\min}$ of the supply channel can be determined from the expression

$$b_{к\min} = 0{,}01 + h_n = \frac{1}{2}\left(0{,}02 - D_б + \sqrt{D_б^2 + \frac{8q}{L_P \cdot \gamma_м \cdot k_1 \cdot \omega_p}}\right), \quad (1)$$

where h_n – length of rotor finger, m;

$D_б$ – diameter of the drum of the feeding rotor, m;

q – supply of grass mass, kg/s;

L_p – working length of the feeding rotor, m;

$\gamma_м$ – density of the mass captured by the finger, kg/m^3;

k_1 – coefficient of filling of the interdigital volume;

ω_p – angular velocity of the feeding rotor, c^{-1}.

The cross-sectional area $S_к$ of the feeding channel can be determined from the expression

$$S_к = a_к \cdot b_к = l_p(z+1)\cdot((0{,}010...0{,}020) + h_n), \quad (2)$$

where z – the number of disc knives in the channel, pcs;

l_p – distance between disc knives, m.

In modern balers and pick-up trucks containing bitters and knife grinders, the cross-sectional area of the feeding channel reaches 1600-2400 cm^2 and - 2800-3700 cm^2, which is 2 times more than in drum shredders.

It should be noted that the height of the feeding channel is almost equal to the length of the rotor finger, taking into account the gap between the bottom of the channel and the end of the finger in the vertical plane, which should be taken within 10… 20 mm. Then the length of the fingers of the feed rotor can be determined from the expression $h_п = b_к - (0{,}010 \ldots 0{,}020)$, м.

The productivity of the bitter-knife shredding machine can be expressed as

$$Q = 60V \cdot \gamma_м \cdot n_p, \quad (3)$$

where V – volume of mass captured by the feeding rotor per rotation, cm^3;

$\gamma_м$ – density of plant mass, kg/m^3;

n_p – rotor speed, rpm.

For one rotation of the feeding rotor, the volume V is captured by the fingers of all rows, which is equal to the product of the volume captured by one finger $V_1$by the number of rows of fingers (i) and the number of fingers in a row ($z+1$), ie

$$V = V_1 \cdot i \cdot (z+1), \quad (4)$$

where V_1 – volume of mass captured by only one finger, m^3.

i – the number of pairs of fingers that are in one vertical cutting plane by 2π;

z – number of disc knives in the channel, pcs.

On the other hand, the value of V_1 can be expressed (Fig. 2) as the product of the area of the ring, which is formed by the rotation of the rotor with one finger length h_n on the distance between the fingers (l_p) attributed to the number of rows of fingers (i)

$$V_1 = \pi h_n \left(D_б + h_n\right) \frac{l_p}{i}, \quad (5)$$

where $D_б$ – diameter of the rotor drum, m.

Since the volume between the fingers cannot be completely filled, we introduce the coefficient $k_1 \le 1$, which determines the amount of filling of the interdigital volume [3, 13]. The dependence of the productivity of the bitter-knife shredding device will look like

$$Q = 60\pi h_n \left(D_б + h_n\right) \cdot l_p \cdot \left(z+1\right) \cdot \gamma_м \cdot n_p \cdot k_1, (6)$$

where l_p – distance between the fingers in a row (distance between the knives), m;

k_1 – coefficient of filling of the interdigital volume.

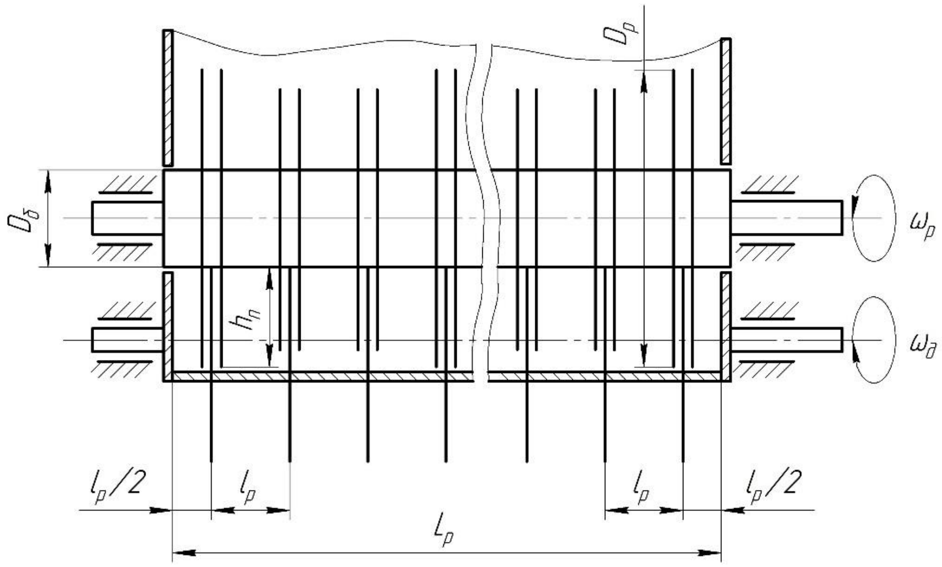

Fig. 2. Scheme of the longitudinal section of the grinding machine

Given that the length of the feeding rotor $L_p = (z+1) \cdot l_p$, and the rotor speed $n_p = 30\omega_p/\pi$, we can write

$$Q = 1800 h_n \left(D_б + h_n\right) \cdot L_p \cdot \gamma_м \cdot k_1 \cdot \omega_p. \quad (7)$$

As can be seen from the dependence (7), the productivity of the grinding device is directly proportional to the length of the finger (h_n), the magnitude ($D_б + h_n$), the length (L_p), the angular velocity of the rotor (ω_p) and the mass density ($\gamma_м$) that is cut. At the maximum value of the mass density 100 – 250, kg/m ^{3} (depending on humidity), the length of the rotor L_p = 1.2 m and fingers h_n = 0.1 m, the diameter of the rotor drum $D_б$ = 0.4 m and the rotation speed n_p = 100 rpm min ($\omega_p = \pi \cdot n_p/30$) drum capacity will be 55 - 280 t/h. Taking into account the coefficient k_1 = 0.3–0.7, the value of productivity will be 20 - 190 t/h (Fig. 3).

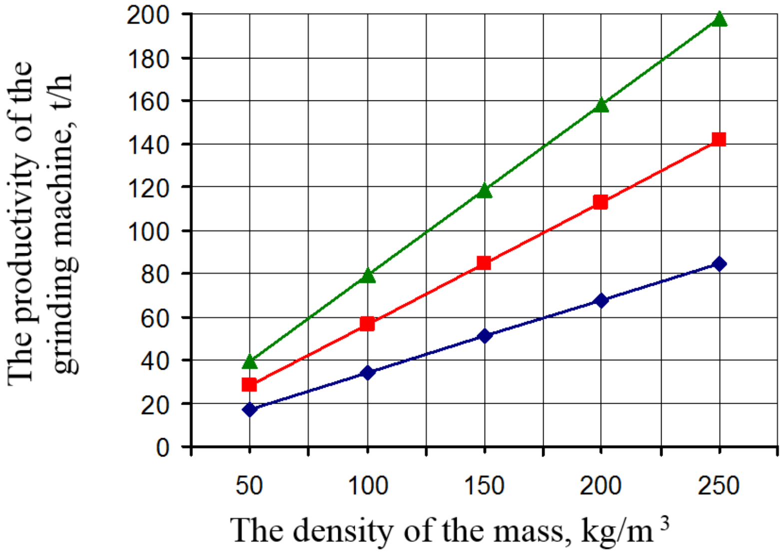

Fig. 3. Graph of the dependence of the productivity of the grinding machine on the density of the mass at the values of the filling factor of the interdigital volume: 1 – k_1 = 0,3; 2 – k_1 = 0,5; 3 – k_1 = 0,7

Conclusions.

1. The quality of stem fodder can be improved by reducing the loss of light fractions (leaves, buds and inflorescences) from the roll of grass mass in the process of its selection. For this purpose, when harvesting haylage, preference should be given to pick-up trucks, balers in which a bitter-knife shredder is used for cutting, which simultaneously with loading by pushing the selected mass ensures its cutting in a closed channel.

2. The maximum capacity of forage harvesters, and from their productivity, is achieved at rational values of the cross-sectional area of the receiving neck, ie the height and width of the feeding channel. Thus, the value of the cross-sectional area of the feeding channel in balers reaches 1600-2400 cm^2, and in balers 2800-3700 cm^2, which is 2 times more than in drum shredders.

3. The dependence (1) has been established, which allows to determine the minimum height of the feeding channel taking into account the design parameters of the rotor and the capacity of the shredding machine.

4. The dependence (7) has been obtained, which allows to determine the productivity of the biter-knife shredder from the finger length of the feeding rotor, the average diameter of the finger rotation, the length and angular velocity of the rotor, the density of leaf mass and the filling factor of the interdigital volume.

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