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SELECTION OF EQUIPMENT FOR PROCESSING ANCIENT GRAINS

Annotation

Recently, there has been a sharp increase in interest in the consumption of ancient grain crops (spelt, einkorn, emmer). In this connection, the sown areas for these crops are increasing, and the main volume of grown cereals is not for animal consumption, but for human consumption. Such a shift in consumption leads to increased requirements for the quality of grain and its processing products. Taking into account the increase in processing volumes, it is necessary to use serial high-performance equipment, which, unfortunately, does not satisfy grain processors due to the peculiarities of the structure of the grain and ears of these grain crops, which affects its efficiency. The paper considers various designs of huskers that are trying to be used in husking spelt and other grain crops. Their technological schemes have been built and analyzed from the point of view of the efficiency of spelt processing. This allowed us to group different designs of huskers and summarize their technological capabilities. Technological schemes with different peeling machines (peeling machine with abrasive discs, with rubber shafts, centrifugal action, impact peelers using a vibropneumatic table and friction separator) were analyzed, which have their own characteristics in separating peeled grain from unpeeled. A general abbreviated technological scheme for cleaning and peeling spelt grain was considered. Its variations in terms of practical application were indicated. A peeler design with an improved scheme for installing a sieve basket was developed. When introducing the newly created equipment at the enterprises of the industry, it was found that the use of an impact-peeling machine allows to improve economic performance: increase labor productivity by 1.375 times, reduce specific electricity consumption by 3.3 kW, obtain a profit of 290,153 UAH, recoup capital investments in 2.12 years, which is economically feasible. The calculations performed indicate the economic feasibility and economic efficiency of improving the impact-peeling machine.

Key words: dehusking, spelt, einkorn, emmer.

Introduction

In the modern world, more and more people are allergic to gluten, which is part of wheat. Cereals such as spelled have significantly less gluten than soft and durum wheat. Therefore, the views turned to ancient grain crops. Increasing the acreage for such crops as spelled, spelt, emmer, einkorn and others requires appropriate efficient and productive equipment. Unfortunately, some features of these ancient grains do not allow us to process them on the existing technological equipment.

From the technological equipment existing at farmers, bone breakers, upholstery machines of various types and other machines are used [1]. Many are upgrading existing equipment or developing their own designs. At the same time, the efficiency of the use of these machines remains low, due to clumping of chaff, clogging of input and output channels, which requires stopping the machines and cleaning problem areas. The percentage of shelled grain on some technological machines does not reach 50 per pass. Therefore, 2-3 passes are needed to increase this percentage to 90-95. In addition, the percentage of broken grain increases.

Statement of the problem

The purpose of this work is the construction and analysis of structural diagrams of the existing designs of huskers and separators for separating grain into husked and unhusked.

The methodology of this study consisted in the sequential execution of the following procedures in the analysis of structural solutions of peelers: structural division of the structure into various technological devices and mechanisms; compilation and analysis of schemes of existing structures; development and selection of common features for the classification of constructions of technological mechanisms; analysis of advantages and disadvantages of selected technological machines.

Research is aimed at choosing the most optimal equipment for performing the main operations of the technological process - peeling and separation at various stages. The optimization of technological operations is performed both from the point of view of reducing energy costs and increasing the percentage of initial grain use and the quality of output products (for example, reducing the number of broken kernels) [2-6].

Results of the study and their discussion

Let's consider the design schemes of machines that are most suitable for performing the technological operation of peeling and are used in the processing of ancient cereal crops.

In Fig. 1a presents a diagram of a husking station used in the processing of a number of grain crops (barley, rice, buckwheat, millet). The peeling machine

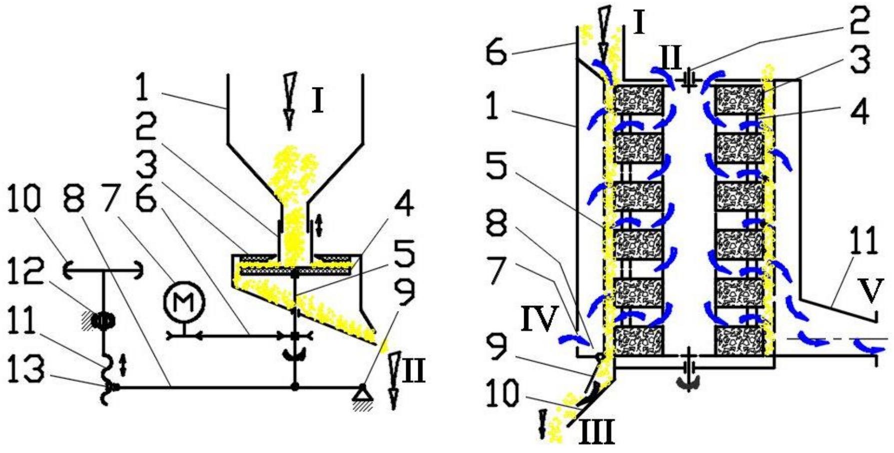

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Fig. 1. Schemes of peelers with abrasive working bodies.

consists of a bed with a vertical shaft 5 mounted on it in bearings, which carries a movable cast-iron disk with a cast annular abrasive mass 4 (Fig. 1a). Above the disk 4 is a stationary disk 3 of similar design, the parallelism of which, in relation to the disk 5, is adjusted using screw devices. To adjust productivity, the machine is equipped with a movable telescopic nozzle 2 and a funnel 1. A drive pulley of a belt transmission 6 is also installed on shaft 5. To adjust the working gap between the movable and stationary abrasive discs, the vertical shaft 5 has the ability to move in the vertical direction, the bearing housing, behind with the help of a screw mechanism 11. To remove peeling products, races are fixed on the lower disc 4, which pick up peeling products and move them to the outlet.

The grain enters the funnel 1, then enters between the nozzle 2 and the plane of the lower rotating disk 4, and is evenly distributed around the circle and thrown by the lower rotating disk into the working space created between two abrasive annular surfaces. In the inter-annular space, the grain feels compressive forces due to the small distance between the discs, the rotation of the disc 4 and friction against its surface, as well as the surface of the disc 3. In addition, the grains feel friction between themselves. Therefore, the shell of the grain lags behind the kernel, if it is a culture such as buckwheat or oats, or the shell that has grown is partially removed, due to microcuts with abrasive particles, if wheat or barley is processed. The grain, having made a spiral movement in the working zone, leaves the husking zone between the two discs and is discharged through the outlet nozzle. Unfortunately, the increased number of shell particles leads to their abrasion and ineffective effect on the core, which is destroyed due to fragility.

During operation, the productivity is adjusted by changing the distance between the lower edge of the nozzle 2 and the surface of the disk 4. When the amount of broken grain coming out of the machine is increased, the position of the lower rotating disk 4 is changed. For this, the screw mechanism 11, lower the bearing housing, together with the shaft 5 abrasive disk 4, achieving more efficient operation of the machine. It should be taken into account that for more efficient use of husking stands, the grain is divided into several fractions according to its geometric dimensions before husking, which, with rigid dimensions of the working gap, leads to a decrease in broken grain at the output. However, this separation is difficult for spelled.

Hulling and grinding machines for barley and wheat type A1-ZSHN-3, which are in use, have the scheme presented in Fig. 1b. A hollow shaft 2 with abrasive discs 3 is vertically installed in the body 1. Spacer perforated rings are installed between these discs 4. There is a mesh cylindrical sleeve 5 around the abrasive discs 3. A receiving device 6 is mounted in the upper part of the body 1. Process air (flow II), enters the machine through the upper end of the hollow shaft 2, in addition, air (flow IV) enters the machine through an adjustable window 7 in the housing 1 to exclude the stagnant zone 8 in the machine housing, which is clogged with shell products. The output of husked grain from the machine through tray 10 (stream III) is regulated by means of a cargo valve 9 or a latch. Process air with shell products is sucked from the machine through nozzle 11 (flow V).

Hullers with rubber rollers are used for peeling grains of crops in which the core is fragile and the shell has not joined the core. The peeling principle is quite simple. Grain is fed between two rotating rubber rollers in different directions at different speeds, while the working gap between the rollers is adjusted so as to eliminate excessive pressure on the grain, and as a result, reduce the number of broken grains (Fig. 2a). The grain experiences compressive forces because the working size between the cylindrical rolling surfaces is smaller than the dimensions of the grain. In addition, due to the difference in linear speeds of the working surfaces

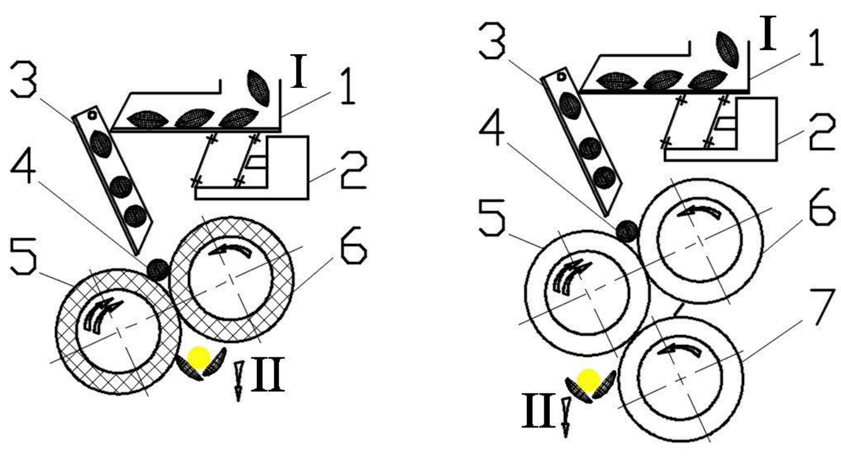

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Fig. 2. Schemes of peelers with elastic working bodies.

of the rolls, the grain undergoes shear forces. This leads to the displacement of the shell relative to the nucleus and its release.

Taking into account that some of the kernels remain with the shell after this operation, sometimes in simpler designs three cylindrical shelling heads are used (Fig. 2b). This allows, firstly, to remove with air some of the separated shells from the main product flow, and secondly, to adjust the working gap between the second pair of rollers to be smaller, and thus contribute to increasing the overall efficiency of peeling in one pass through the machine. It should be noted that the service life of the rolls is about 200 hours.

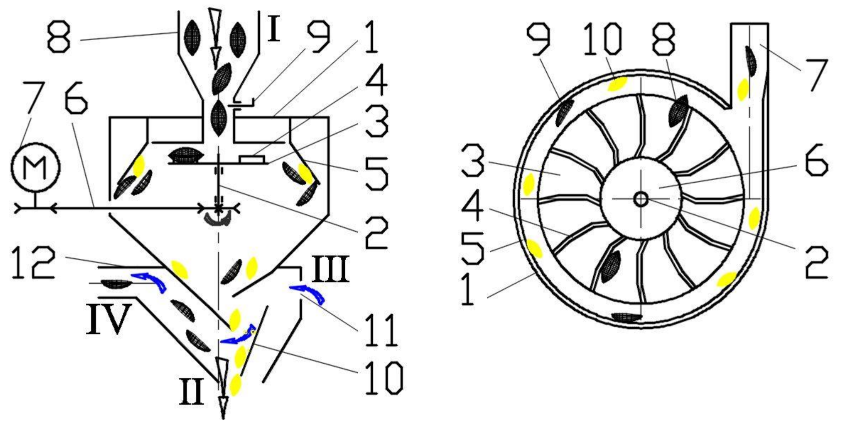

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Fig. 3. Schemes of centrifugal peelers.

It is very important how the grain is fed into the interroller gap and in what quantity. Therefore, a some firms of Satake and Schule companies, including Buhler, use a vibrating feeder 1, which ensures the specified productivity and uniform feeding along the entire length of the rolls, as well as stopping when the working rolls fall off. An electromagnetic vibrator 2 is used to drive the tray 1. In addition, an adjustable tray 3 is used for a more accurate direction of the grains in the working area (the position of the working area is shifted due to the wear of the rolls). When the grain moves along the tray 3, it rotates around the long axis, which helps to orient it more correctly when it is fed into the working area between the fast-rotating roller 5 and the slowly rotating roller 6. It is quite easy to implement this decision on a grain of rice, which is practically impossible when spelled processing.

The Schule company solves the problem of uneven grain entering the husker by means of an elastic hopper, which lowers under the weight of the incoming grain and includes a valve that stops the roller system. In the absence of grain arrival, the hopper rises and the system carries out dumping.

The rolls are made of rubber with a hardness of 85-90 Shore units. Rubberized rollers with an outer diameter of 200 mm have low performance indicators, so companies mainly offer polyurethane rollers. In addition, to reduce the operating temperature of the rolls, they are sometimes intensively blown by individual fans, as provided for in the design of the Schule machine.

The application of shock during the collapse of sunflower seeds has been used since ancient times. When husking oats, various machines were used, but mainly husking machines and upholstery machines. Recently, centrifugal peelers (Fig. 3a) have been used, which have slightly better characteristics compared to the technological equipment used earlier [7]. The impact of the compression force on the grain when hitting a fixed or rotating steel deck (sometimes the deck is made of stone, ceramics or polymers) is enough to open the shell. At the same time, the grain must be oriented in such a way that the impact falls along its long axis.

The centrifugal peeler consists of a body 1, a vertical shaft 2 in bearings placed in it. A disk 3 with guide vanes 4 is attached to the shaft 2. A cylindrical or conical deck 5 is attached to the body. The drive of the shaft with the disc is carried out through the belt transmission 6 from the electric motor 7. In addition, the peeler is equipped with a receiving hopper 8 with a feed valve 9.

Sometimes an air separator is installed in the lower part of the machine. In the body 1 there is a row of shelves (trays) 10 through which the peeling products (kernels and shell products) move and fall under the influence of the horizontal air jet entering through the slot 11 in the peeler body. Dust, casings and air are sucked out of the machine through the nozzle 12. With the help of the latch 9, the inflow of grain into the machine is regulated.

Centrifugal huskers with a horizontal shaft of rotation are used mainly for husking rice grains (Fig. 3b). A horizontal shaft 2 with a disc 3 on which the guides 4 are fixed is installed in the housing 1. The cylindrical part of the housing 1 is lined with a polyurethane shell 5 from the inside. Also, a tangential outlet nozzle 7 is located on the housing 1.

Paddy grain of rice is fed into the central zone 6 where, under the influence of centrifugal forces, it is thrown onto the guides 4, which have radial grooves. The grain is oriented by these grooves and its long axis takes a radial direction. When exiting the guides, the oriented grain 8 hits the polyurethane lining 5, while the shell of the grain 9 loses its stability and the core 10 separates from the shell. The air flow created by the disk 3 with the guides 4 picks up the kernels, shells and unshelled grains and is removed through the outlet pipe 7.

It should be noted that centrifugal huskers work effectively on grains of an oblong shape, which is characteristic of rice and oat grains. At the same time, the grains of spelled and other similar crops, covered with shells, have a shape that is far from elongated. Therefore, in the latest developments of peelers for ancient cultures, the centrifugal method is not used.

Consider the peeling scheme used in the combined machine of the Horn company, specially designed for peeling spelled (Fig. 4a) [8]. In housing 1, a shaft 2 is installed in bearings, on which a rotor is fixed, consisting of a disk 3 with balls 4. The rotor is located in a screen housing 5. In the upper part of housing 1, a power supply nozzle 6 is mounted, and at the bottom is a

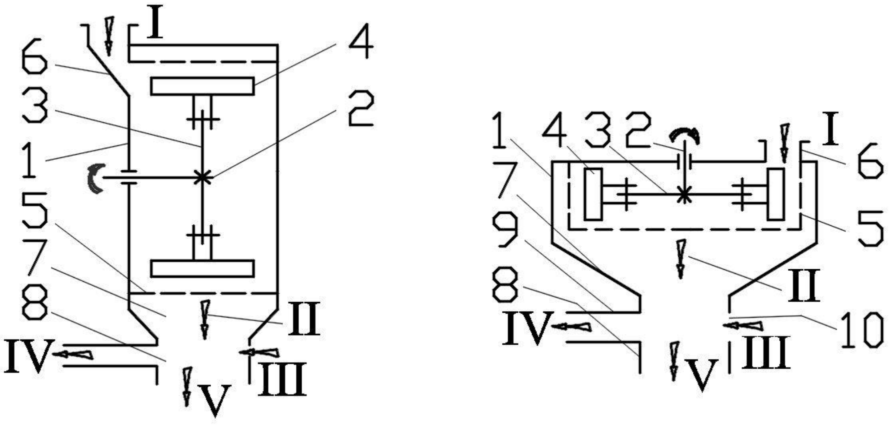

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Fig. 4. Schemes of impact peelers.

collection and output device 7 with an air separator 8.

The peeler works as follows. The initial material enters the feeding nozzle 6 (flow I) and is picked up by rotating bales 4. At the same time, the grains experience both shock loads and the effect of friction from movement along the sieve tube 5. The grain and separated parts of the shell pass through the sieve tube 5 (flow II) and intensively blown by air flow III. Shell particles are picked up by the air stream and are referred to the aspiration network (stream IV). Cleaned grain exits the huller in the form of stream V. The effectiveness of this hulling operation depends on a correctly selected sieve, as indicated by a number of publications [2, 3, 4]. At the same time, the variation of geometric dimensions in a batch of grain affects the number of broken grains and an increase in the percentage of returned unhusked grain.

In order to increase the sieve surface and increase the probability of passage of the separated core and shell particles, the peeling scheme shown in Fig. 4b. The layout of the peeling rotor has changed, it became with a vertical axis of rotation, which made it possible to increase the area of the sieve surface and, as a result, leads to a decrease in the time spent in the impact working zone and a decrease in the percentage of broken kernels. In this design scheme, the conditions for replacing a single sieve basket are improved, which affects the productivity of the entire spelled processing line. Other elements of the peeler scheme remain similar to the previously discussed peeler with a horizontal shaft of the Horn company.

In the last two schemes of huskers, it is possible to clog the holes of the sieve surface with particles of spelled grain shells, so the problem of cleaning the sieve shell becomes urgent.

Consider the scheme of a two-blade peeler (Fig. 5a). From the electric motor 1, the movement is transmitted through the belt transmission 2, 3, 4 to the shaft of the peeler I. There is a feeding screw 8 on the shaft I. The shaft I with the screw 8 are located in the bearings 5 of the housing 6. A hopper 7 with the product is mounted above the housing 6. A hollow rotor 9 with protrusions 10 and windows 11 is also mounted on the shaft I for blowing the working area of the peeler with air. Fixed plates with protrusions 12 are installed on the housing 6. Part of the hexagonal housing 6 is covered with a net 13. A weight valve 14 is mounted at the exit from the peeler. Also, at the output end of the hollow shaft I, a nozzle 15 is mounted for supplying high-pressure air to the working area of the peeler.

From the hopper 7, the grain is fed by an auger 8 into the working area, where the rotor 9 with protrusions 10 picks up the grain and rubs it against the plates with protrusions 12 and sieve surfaces 13. Also, the grain in the working area experiences impulse loads from mutual friction. The husks and husks are intensively blown out of the working area through the sieve surface 13. The husked grain is released from the husker by turning the weighing valve 14.

It should be noted that the husker designed for rice is not quite suitable for processing spelled grain, which has a very high percentage of shells.

Let's consider another peeling scheme, which is specially developed for peeling spelled (Fig. 5b). In the housing 1, a cylindrical drum 3 with small slats 4 installed along the linear generators of the cylindrical sur-

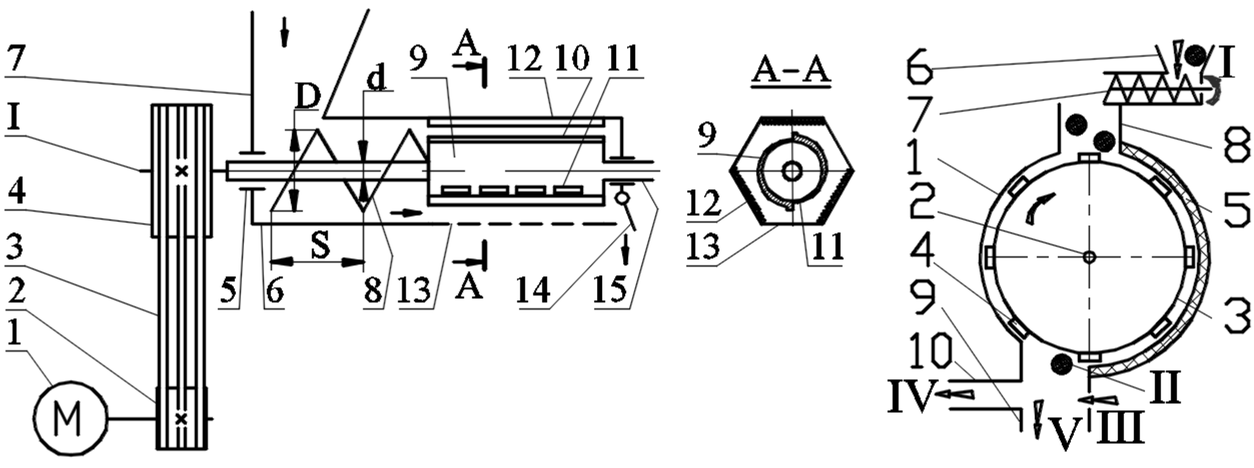

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Fig. 5. Schemes of peelers for spelled.

face is installed on the shaft 2. Part of the inner cylindrical surface of the housing 1 is covered with sheet rubber 5. In the upper part of the peeler, a screw feeder 7 with a hopper 6 is mounted. The upper part of the peeling body 1 has an intake pipe 8. An outlet pipe 10 is mounted in the lower part of the housing 1.

The peeler works as follows. From the hopper 6, the raw material (stream I) is fed by the screw feeder 7 to the receiving nozzle 8 of the peeler. The grain with the shell falls on the cylindrical surface of the drum 3, is picked up by the slats 4, which orient it, while the long axis of the grain is in most cases parallel to the axis of rotation of the drum. This contributes to the rubbing of the grain with the shell against the inner rubber surface 5 of the husking body. Intense compression and shear forces applied from the side of the rubber surface lead to the removal of the shell. The core freed from the shell falls out as stream II together with partially ground particles of the shells. This flow is intensively blown by process air (flow III), which contributes to the removal of aerodynamically light particles together with the air flow into the aspiration network (flow IV). The spelled kernel, cleaned of aerodynamically light particles, exits the huller in the form of a V stream.

Hulled and unhulled grains of ancient cereals coming out of the hulling machine are a mixture that is difficult to separate. Pneumatic sorting tables and friction separators are most suitable for separating paddy grain from the kernel (Fig. 6).

Let's consider the movement of the components of the mixture along the tray of the pneumatic sorting table, top view (Fig. 6a). The scheme of the pneumatic sorting table consists of the following elements: tray 1, latches 2, bumper 3, valves 4, which make up the side wall, open valves 5, receiving trays 6, 7, 8, 9, as well as cutting bars 10.

The initial mixture, flow I enters the uppermost edge of the tray (Fig. 6a). The deck is made of metal woven screen and has slopes in the longitudinal (angle α) and transverse directions (angle β). In addition, in the transverse direction, reefs from the corner are installed on the sieve surface, which prevent the movement of the lower fraction of the grain layer in the longitudinal direction. The grain layer is self-sorted in zone 10 under the influence of the vibration of the deck and the air blowing from below, while heavy particles (core) fall to the lower layers, on the metal woven sieve surface, and light particles rise to the upper layers. Heavy particles (mainly mineral impurities) have a hard time overcoming the transverse grooves, so they have a greater speed of movement in the transverse direction, and they move along the deck and flow down through the gap formed by the latch 2 with the plane of the deck 1. For more effective retention of the mineral admixture, a baffle 3. The most aerodynamically light particles that have risen to the upper layers move freely in the longitudinal direction (zone 11) and leave stream II.

Heavy and mixed grain fractions move in the longitudinal and transverse directions during the movement of the grain layer across the surface of the deck, so they move in almost parallel streams in zones 13 and 12 and leave the surface of the deck. If it is a mixture with a large amount of core, then to increase the efficiency of separation, it is possible to open the rotary valves 5 on one of the side walls of the pneumatic table and carry out the selection of the heavy fraction of the core V, since the mineral admixture is previously selected. The selection of the heavy fraction allows to reduce the load on the surface of the deck and to carry out a better division into fractions (in this case III and IV, although there may be more fractions) at the unloading edge of the deck. Usually fractions IV and V are combined into one transport flow.

As follows from the literature, farmers mainly use pneumatic tables, which are in the grain cleaning department. To increase the separation efficiency, the Horn company developed a friction separator, the diagram of which is shown in fig. 6b. It should be noted that similar designs of machines based on the friction principle of operation were used for the separation of mineral impurities (for example, the A1-BKM stone-separating machine).

The grain mixture from the core and paddy grain enters the stream I through the nozzle 1 onto the surface of the deck 2, which receives circular translational movements. In zone II, the grain mixture is separated, the core is thrown to the periphery of the tray and is advanced by flow III. The unhusked grain rises to the upper layers and is directed to the center of the tray, where it is discharged from the separator through hole 4 in the form of flow IV, and returned to the husking. The formed flow of core III passes almost in a circle and exits through

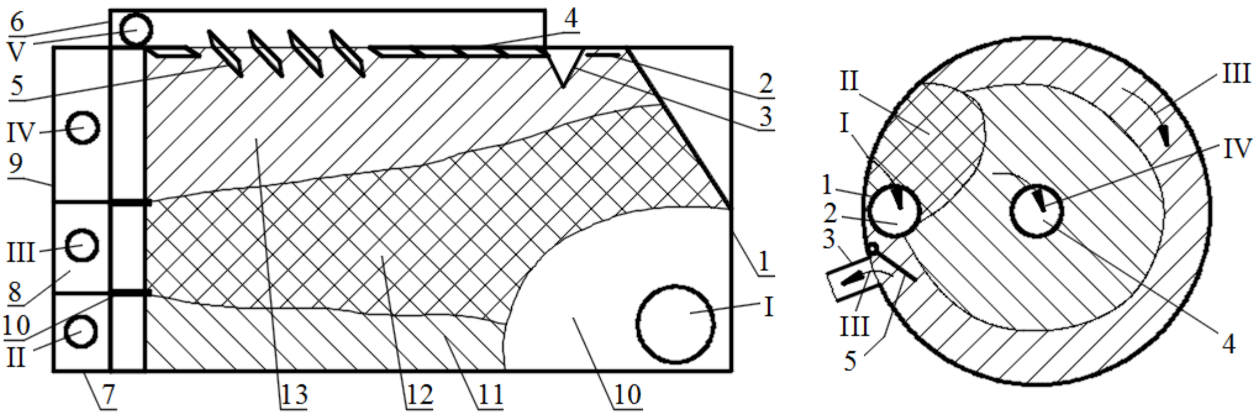

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Fig. 6. Schemes of the vibro-pneumatic table a) and the friction separator b).

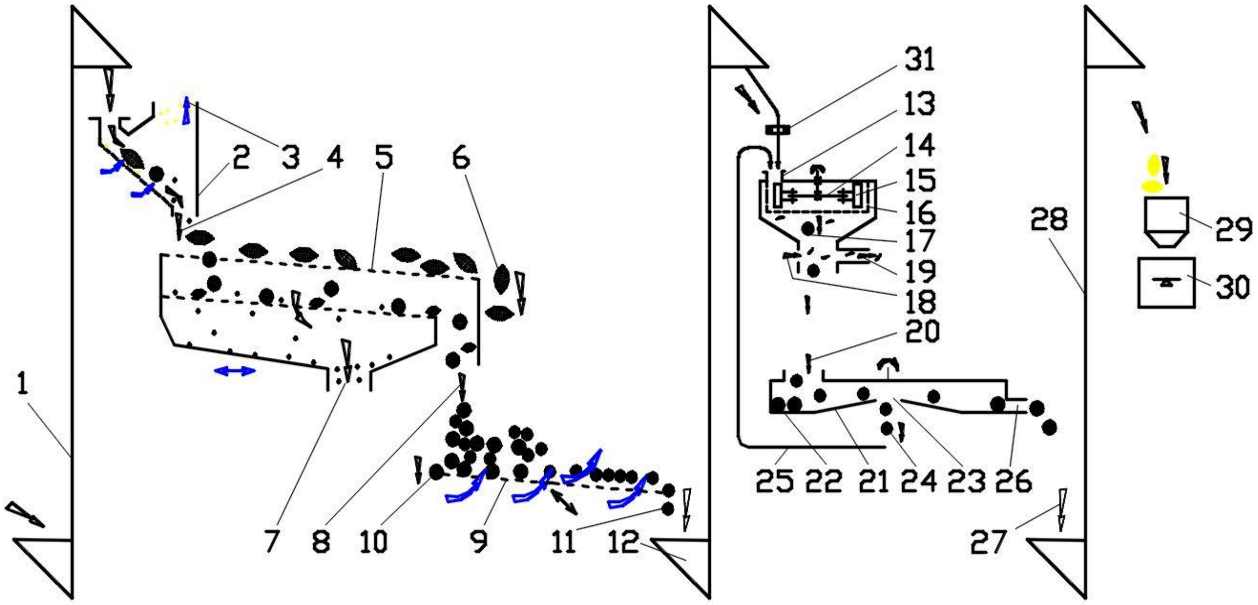

Fig. 7. Scheme of the technological line of cleaning and peeling of spelled.

nozzle 3.

The width of the removed flow depends on the adjustment of valve 5. Its position regulates the performance of the separator, as well as the efficiency of work. Some part of the mixed flow (kernel and paddy grain) returns to zone II and the whole circular cycle is repeated.

Considering the simpler design of the friction separator compared to the pneumatic sorting table, the choice remains with the first one.

Let's consider the abbreviated technological scheme of spelled grain cleaning (Fig. 7). The grain is lifted by the noria 1 to be cleaned by the air flow in the shutter separator 2. The air separator 2 is very often mounted on the material pipeline itself. Aerodynamically light particles 3 are removed from the grain mixture, and the main grain flow 4 enters the sieve separator 5. Large impurities 6 leave the upper sieve, small impurities pass through the lower sieve and are removed in the form of flow 7. The main grain flow 8 leaves the sieve separator and served on the tray of stone picker 9. Mineral impurities are removed in the form of flow 10, and the main flow of cleaned grain is fed to the noria 12, from which it passes through the magnetic separator 31, where ferromagnetic impurities are removed.

After cleaning, the grain is sent to the impact huller 13, in the housing of which there is a rotor 14 with hammers 15. Around the rotor there is a sieve cloth 16, through which, after impact and intense friction, the core, shells and unhulled grain (stream 17) pass. This mixture is blown by an air flow 18, which picks up the husks and small dust particles and removes them, flow 19. The kernel and paddy grain are fed to a friction separator (flow 20), where on the tray 21, which receives circular translational movements, the kernel is thrown to the periphery 22, and after passing a certain angle in a circle, it exits through the nozzle 26. Unhusked grain, as it is easier is collected in the center of the deck 21, and exits through the opening 23 in the form of a flow 24, which is directed to re-husking by means of an auger or a pneumatic conveyor 25. The core flow 27 is sent to the noria 28, from which it enters the operational bunker 29, and then to the scales 30.

According to the scheme of the technological line of cleaning and shelling of spelled grain, the most promising equipment is an impact shelling machine. Improvement of this machine by installing a frequency converter of the speed of the main electric motor allows to obtain a preliminary economic effect. At the same time, the operation of the impact peeling machine will improve the economic indicators of operation:

- increase productivity by 1.375 times;
- reduce specific electricity needs from 13.5 kW to 10.2 kW;
- get a profit in the amount of UAH 290153;
- pay off capital investments in economically justified terms in 2.12 years.

Conclusions

1. Technological equipment that can be used for additional peeling of ancient cereal crops is considered. Its advantages and disadvantages are revealed.

2. The scheme of grain hulling and selection of hulled grain from unshelled grain is presented.

3. The design of the peeler with an improved scheme for installing the sieve basket has been developed.

4. The economic aspects of the introduction of newly created equipment at the enterprises of the industry were analyzed. The calculations indicate the economic feasibility and economic efficiency of the improvement of the impact peeling machine.

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ВИБІР ОБЛАДНАННЯ ДЛЯ ПЕРЕРОБКИ СТАРОДАВНІХ ЗЕРНОВИХ КУЛЬТУР

Анотація

Останнім часом різко зріс інтерес до споживання давніх зернових культур (спельта, однозернянка, емер). У зв'язку з цим збільшуються посівні площі під ці культури, причому основний обсяг вирощених злаків йде не на споживання тваринами, а людині. Таке зміщення у споживанні призводить до посилення вимог до якості зерна і продуктів його переробки. Враховуючи збільшення обсягів переробки, необхідно застосувати серійне високопродуктивне обладнання, яке, на жаль, не задовольняє переробників зернової продукції через особливості будови зерна та колосу цих зернових культур, що позначається на його ефективності роботи. В роботі розглянуті різні конструкції лущильників, які намагаються застосувати при лущені спельти та інших зернових культур. Побудовано та проаналізовано їх технологічні схеми, с точки зору ефективності переробки спельти. Це дозволило згрупувати різні конструкції лущильників і узагальнити їх технологічні можливості. Проаналізовано технологічні схеми з різними лущильними машинами (лущильна машина з абразивними дисками, з гумовими валами, відцентрової дії, ударних лущилок з використанням вібро-пневматичного столу і фрикційного сепаратора), які мають свої особливості при виділенні лущеного зерна від нелущеного. Розглянуто загальну скорочену технологічну схему очистки та лущення зерна спельти. Зазначені її варіації що до практичного застосування. Розроблено конструкцію лущилки з удосконаленою схемою встановлення ситового кошика. При впровадженні новоствореного обладнання на підприємствах галузі було встановлено, що використання ударно-пілінгової машини дозволяє покращити економічні показники роботи: підвищити продуктивність праці в 1,375 рази, зменшити питомі витрати електроенергії з на 3,3 кВт, отримати прибуток у розміру 290153 грн., окупити капітальні вкладення за 2,12 років, що є економічно доцільно. Проведені розрахунки свідчать про економічну доцільність та економічну ефективність удосконалення ударно-лущильної машини.

Ключові слова: лущення, спельта, однозернянка, емер.

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