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TECHNICAL SOLUTION FOR PROCESSING OF FLAX RAW MATERIALS

Theory and practice of technical upgrade of factories processing flax raw material, modernization of production, the application of advanced technologies and equipment have been discussed. The results of simulation of cleaning of flax fibers from non-fibrous impurities have been analyzed for various options and configurations of equipment. The possibility and expedience of application of innovative solutions for improving physical and mechanical properties and quality of flax raw material have been proved. The conditions for development of the processing industry in Ukraine and achieving of positive results from processing of stem flax material using innovative processing technologies, advanced technical solutions, and original methods of processing by new equipment have been described.

Keywords: fiber, flax, raw material, quality, cleaning, processing, equipment, and production.

Flax is one of the most common crops in the world, which has three portions: seeds, fiber, and boon. All of them are a natural recyclable raw material for many industries. In Ukraine, flax is planted in various regions, mainly, in the North West. Fibers obtained from linen (long-stalked) flax, oil flax, and other varieties are used in textile industry for the manufacture of interior fabrics, apparel, footwear, technical textile materials and products, linen cottonized fiber, paper and cardboard, cords and ropes, and composite materials for different purpose. The boon obtained as a result of processing of flax is used as insulating building material; loose fiber waste of linen production is used to produce heat and sound insulating materials for construction, cleaning cloths and other technical materials. The oil obtained from flaxseed is rich in omega-3-linolenic acid widely used as a valuable supplement.

Despite the production of bast-fiber plants is quite profitable in Ukraine, their acreage declines every year. Accordingly, the production of fibers also slumps, while import of raw materials steadily grows.

As a result of constant pressure on the domestic market of raw materials, in Ukraine, the flax and hemp business is declining, which affects situation in the manufacture of goods from bast-fiber materials. The statistical data of the 21st century showed the production of fibers fell 4 times, that of linen fabrics dropped 6 times, as a result of reduction in acreage, deterioration of quality of raw materials, a significant increase in the use of synthetic materials, economic and financial crises and decrease in population income [1]. In addition, the production is significantly affected by aging of equipment and machinery, significant depreciation of existing equipment, use of outdated technologies, lack of effective schemes for modernization of production facilities for improving quality and expanding the range of products.

Although the crisis is sizeable enough, it can be overcome by stimulating consumer demand for environment friendly products made of bast raw material, insofar as it is used in almost all sectors of the economy and life. To provide high-quality

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goods from vegetable material it is necessary to apply modern advanced technology and sophisticated know-hows.

The growing competitive environment in the domestic market entails the need to upgrade inefficient old technologies for processing stem materials and obsolete equipment, to carefully use the natural resources in order to expand the possible benefits of vegetable renewable resource based on flax and hemp. Therefore, the current state of production in Ukraine requires to find and to develop innovative and attractive technical and technological solutions for improving the quality of products and their environmental safety, for ensuing economic independence from foreign supplies of raw materials and for expanding the assortment of products.

The theory and practice of re-equipment of enterprises, upgrade of their production facilities, and use of advanced technology and equipment for processing of flax raw materials as described in [2—9] give reason to believe that at the current stage of development of this industry of Ukraine it is possible to achieve remarkable results in processing of flax stem materials, especially, those little used, due to innovative technologies taking into account the physical, mechanical, and anatomical peculiarities of plant stems, modern trends in the consumer market, advanced technical solutions, and original methods of their treatment with new substances.

The studies have showed that the conventional flax stem processing technology based on division into long and short fibers is inexpedient and that efficiency of the use of existing production facilities is quite low. The assessment of technological capabilities described in [7, 8] indicates that in order to obtain a homogeneous fibrous mass, mainly, from treated fibers, it is necessary to use various bulky equipment.

In Ukraine, the Institute for Bast Crops of the NAAS of Ukraine has been successfully working at addressing issues related to efficiency of primary processing of bast crops. Within the UAAN *Bast Crops* target complex program for 2006—2010, an innovative technology for obtaining long flax fibers by deeply differentiated mechanical action on the stem has been developed, which enables to increase the share of long fibers, and a technique for obtaining consistent flax and hemp fibers with desired quality characteristics has been proposed. That research is focused on solving issues related to the effectiveness of the scutching part of machines for processing bast raw material and does not pay sufficient attention to the softening that also has a considerable potential for raising the equipment effectiveness.

Currently, the scientific framework for the creation of new technology and knowhow for processing flax stem material is being formed, and advanced modern equipment or its key components are being designed, which can significantly improve the quality and quantitative parameters of the final product. However, for the time being, these problems have not been completely solved from the standpoint of design and application of nodes and connections of softening and scotching machine, which can improve cleaning of raw flax due to implementation of some engineering solutions.

Recent global noticeable trend is development and wide use of environment friendly processes. To this end, it is very relevant to lay methodological foundations for searching directions where the society can become more ecologically sound, for instance, by manufacturing semi-finished products that contain a low percentage of synthetic materials and are of high quality and safe for environment, human health, and property.

Unfortunately, the problem of application of processed bast fibers has not been completely solved, no general methods for obtaining fibrous material have been developed, while the machinery used has a large number of elements, which affects the metal and energy consumption and reduces its productivity and cost-effectiveness.

The research was aimed at searching ways and designing structural transformations of equipment for processing flax materials, which, due to innovative solutions, would be able to improve both quantitative and qualitative indicators of processed flax stems. The authors have offered new directions for the development of textile industry, specific techniques for processing of raw bast materials, and ways to improve the technical level of equipment and machinery.

RESULTS AND DISCUSSION

Fiber of bast crops is often used for production of goods for industrial application, including for food, defense, automotive and other industries. Wide range of products includes not only flax and hemp doublings (yarn, cables, ropes, and cords), but also other fibrous nonwoven materials, including cotton and medical dressing materials which have as good characteristics as their cotton counterparts. Flax fiber is used to make the finest surgical thread that is highly compatible with human body tissues.

Ukraine's climate is unfavorable for the cultivation of cotton, therefore, to ensure economic independence it is important to have domestic pulp and fibrous raw materials to produce cloth for the army, nonwoven materials, dust, wool, medical yarn and explosive materials from flax nitrocellulose.

Demand for fiber flax production is quite significant, despite a decrease in acreage. The situation with seeds of bast plants is somewhat different. According to *UkrAgroConsult*, in September 2016, Ukraine exported 4.3 thousand tons of flax seeds as compared with 2.5 thousand tons in August 2016 and 4.6 thousand tons in September 2015 [10].

The tendency to reduce export relative to the first month of the year has been reported for the third consecutive season, while at the end of the season, the export grows sometimes up to record breaking levels. In the 2015—16 season, about 40 thousand tons of oil flax seeds were supplied to foreign markets.

During the first half of 2015—16 season, Ukraine exported 25.13 thousand tons of flax seeds, which was by 52% (or by 8.6 thousand tons) more than in the same period of the previous year [11].

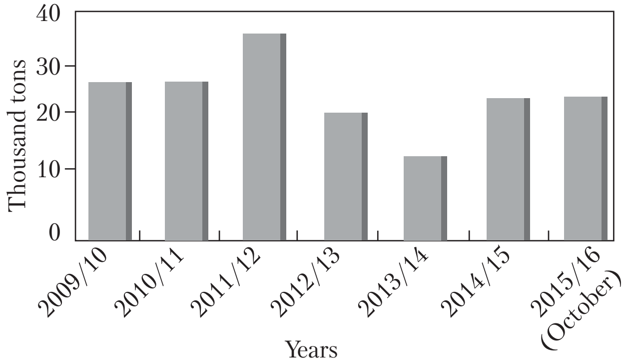

Fig. 1. Dynamics of linseed export for the period 2009/10—2015/16 (thousand tons)

In September 2016, oil flax was sold to 27 countries, including the European Union (53% of total flax exports) that surpassed Vietnam (33%), the leader of the 2015—16 season. Hence, Ukrainian oil flax export has been showing positive dynamics in recent years (Fig. 1) [10].

Export of Ukrainian goods to Turkey has grown significantly: during 6 months 2016, it reached USD 932.4 thousand (2.8 thousand tons) that was 9.7 times higher than in the same period of the previous year. At the same time, flax import to Ukraine increases as well. The main importers to Ukraine are still EU Member States, in particular, France, Germany, and Belgium, as well as Russian Federation [12].

According to *UkrAgroConsult* experts, this is due to recently increased farmer's interest to bast oil plants and consequently growing export potential of Ukraine in this market segment.

The world flax production in 2015/16 season continued to show an upward trend and can reach its peak for 10 years, 2.65 million tons. The growth of world gross flax yield stimulates an increase in acreage under oilseed flax in several key producing countries. In Ukraine, in this season, the area under flax also has reached an absolute record of 62 thousand ha.

However, as oil flax export increases a problem of processing significant amounts of stem material arises. At the same time, it is necessary to process hemp, which also makes considerable contribution to meet oil demand. Available domestic capacities are not enough for processing such a large amount of material, first of all, because of poorly maintained and worn processing equipment. Only a small number of producers has well-conditioned equipment.

The problem of proper equipment is caused not only by a significant wear, but also by lack of its production in Ukraine, no government assistance, and some specific physical, mechanical, and anatomical properties of stems, especially, in terms of its processing.

Until recently, the industrial capacity of domestic enterprises was focused mainly on the processing of flax straw in order to obtain a significant percentage of long fibers. Today, the priorities have shifted towards processing consistent flax stem material to release fibers that can be used for getting mixed masses using cottonization process.

Flax raw materials arriving to be processed by softening machine have heterogeneous physical properties. The domestic bast crops significantly vary in terms of thickness and length of the stem, fiber content, location and length of the elementary fibers. Bast bundles of long-stalked flax consist of longer fibers as compared with those of oil flax. This causes their high strength.

Quality of fiber depends directly on the anatomical structure and external characteristics of the stem. Fiber thinness is determined by diameter of elementary fibers. Longer elementary fibers with smaller diameter give a subtler, and therefore, more valuable fabric. The longer is the elementary fiber, the smaller is the hollow in it and the more multi-faceted are cross-sections. The more fibers constitute the beam, the better and stronger is technical cloth.

The stem of long-stalked flax consists of fibers collected in a broad holistic bundles of regular form. The cross-section of some individual fibers are shaped as polyhedron, with fibers fitting tightly to each other. The stems of varieties of oil flax have bundles of fibers loosely fitting to each other, with irregular serrated edges in cross sections. The average area of bast cell of long-stalked flax is slightly lower than that of oil flax.

Pretreatment of the material depends on the anatomy of fiber bundles and the share of different fibers in the stem. It should be noted that the anatomical structure of stems of long-stalked flax and oil flax significantly differs from each other. The long-stalked flax has a thin and delicate cuticle and a narrow parenchyma, while the oil flax has a coarser cuticle and a thicker and wider parenchyma. The oil flax has a higher content of epidermis in the stem as compared with the long-stalked flax. This is especially true for the middle and upper part of the stem.

Elementary fibers of oil flax varieties are shorter than those of long-stalked flax because of their specific morphological structure therefore the strength of technical cloth made of oil flax fibers is slightly lower. The elementary fibers of oil flax are fluffy and bean-shaped. The majority of bast fibers is in the middle part of the stem. The stem contains the maximum amount of fibers, which is more than 4 times exceeds the amount of fiber in near the root [13].

In the absence of domestic highly efficient processing equipment and simple technology available to farmers and small businesses, in the view of the need to handle large volumes of stem oil flax material and differences in anatomical, physical, and mechanical properties of bast crops as well as stiffer present-day requirements, it is necessary to design node components and equipment for processing flax materials that are more versatile in terms of functionality, in particular, are capable of processing stem materials with various characteristics.

Softening and crumpling are considered the major processes of treating bast crops, since they primarily affect the fiber quality. However, other pretreatment processes, including layering of stems, combing, flattening, parallelization of stems in the layer, structuring and thinning of straw should not be neglected insofar as they also have a significant importance for the outcome of treatment.

Fiber is the major end product of technological operations related to pretreatment of stems of raw bast materials, which requires the use of special machinery. This is primarily because of specific machine treatment of vegetable materials, including the straw that has a peculiar structure of stems. The aim of machine processing of flax stems is to break the structure of stems in a way that enables to get from them as many intact long fibers as possible.

Impact of mechanical load at the edgewise compression of flax stems can be different along the perimeter of cross section. The working bodies of softening machine act on both the single stem and the group of stems in straw layer provided there are no limitations on the sides, but there are similar limitations under the action of compressive loads in mutually perpendicular and other directions [14, 15].

As of today, edgewise compression of stems by rollers in the plane of взаємно направлених сил їх дії are widely used for softening the raw flax. In this system, the stem material is compressed by cylindrical rollers. The edgewise compression of stems can be easily implemented in squashing and softening. While the stems are compressed between the rollers, the bonds of woody tissue with stem are broken from both contacting sides.

It has been established that in the case of edgewise compression the higher is pressure on the stem and the lesser is radius of curve contacting the stem surface, the more material is destruction of bonds. Practically, mechanical processing of bast crops, transversal compression is realized for passing the stems through smooth rollers and compressing the stems in the softening nodes.

In the case of edgewise compression the stem is broken into segments. Under small loads and small diameters, the stem is divided into four segments. As the diameter, inner hollow size and load increase, so does the number of segments. The stem destruction under edgewise compression has several stages.

The first is elastic compression of whole stem, with cross section of the stem deformed and shaped ecliptically. Further, the stem is broken into segments, as a rule, at the beginning, into four ones. In the case of thin-walled stems, under the further compression each segment can additionally split into two ones, whereas in the case of thick-walled stems with small inner hollow no further splitting is reported. The process ends with compression of very stem material. In the case of edgewise compression, the stem resistance to longitudinal splitting at the beginning and in the mid-process is negligible as compared with direct compression of stem material at the end [16—18].

To facilitate the separation of fibers from the stem it is necessary to pretreat the raw material (to squash and to soften), as well as possible in order to make more effective the next stages of stem material processing. To this end, it is critical to create as many centers of woody tissue damage as possible, via applying 3D load in closed space.

Having analyzed the information and data of both experimental and theoretical research, two types of node for cleaning the raw stems from flax straw of scutcher [19—20] have been designed based on facilities of Kherson National Technical University. The node is designed for softening the stems of flax straw to prepare it for scutching. The node is a part of scutcher containing 13 pairs of breaking rollers (smooth, plate, sharp-grained, and sharp-grooved of straight and helical profiles). Some of them have a small radius of profile contour and a relatively low grooves as compared with the step, while others have small radius of groove edge curve and relatively high grooves as compared with their step. They are located pairwise (coupled) to squash and to break the woody tissue of flax stems.

The devices were designed to improve the cleaning of raw material from the straw due to specific configuration that would enable to ensure favorable conditions for breaking or weakening bonds between fibrous part of the stem and woody tissue, to parallelize the stems in the straw layer, and to raise effectiveness of softening/breaking, cleaning, and, consequently, of the operation of entire machine.

The mentioned task is solved due to the fact that the node for cleaning of raw material from the straw of scutcher contains breaking rollers (smooth, plate, sharp-grained, and sharp-grooved of straight and helical profiles) mounted in such a way as to ensure their rotation on the scutcher framework:

- The first way foresees that the node contains, at least, a pair of squashing rollers, each being a hollow cylinder throughout the length of which there are one-side notches of given profile located circle-wise, at a regular step. The steep convex side faces of the profiles ensure a steady minimum gap between the profiles of squashing rollers placed after the pair of smooth breaking rollers before the pair of grooved rollers;
- The second way foresees that the node contains, at least, a pair of squashing rollers. Each roller is a hollow cylinder throughout the length of which there are one-side notches of given profile located circle-wise, at a regular step. Wavy convex side faces of the profiles with wave of the one side face running between waves of the other face ensure a steady minimum gap between the profiles of squashing rollers placed after the pair of smooth breaking rollers before the pair of grooved breaking rollers.

The essential difference between them is that the pair of squashing rollers of the node for cleaning of raw material from flax straw of the scutcher in the second option has rollers throughout the length of which there are one-side notches of given profile located circle-wise, at a regular step. Wavy convex side faces of the profiles, with wave of the one side face running between waves of the other face, ensure a steady minimum gap between the profiles of squashing rollers.

The first option enables to raise effectiveness of conditions for breaking and weakening bonds between the fibrous part of stem and woody tissue due to transversal compression of woody tissue in those parts of the stem, which have not been compressed while squeezing through the pair of smooth squashing rollers and in the course of parallelization of straw stems within the indrawn layer due to pass of stems through quite narrow one-side notches of given profile with steep convex side faces and transmission of required load on the material through a larger contact area as compared with the smooth rollers. This creates conditions for appearance of many centers of shear load or tangential shearing stress, which raises effectiveness of breaking and cleaning on the grooved rollers of softening machine.

The second option enables to raise effectiveness of conditions for breaking and weakening bonds between the fibrous part of stem and the woody tissue due to transversal compression of woody tissue in those parts of the stem, which have not been compressed while passing through the pair of smooth squashing rollers, in the course of bending-breaking and pressing of the layer of material in the cavity between projections on waves, which causes significant tensions in the fiber, in the course of parallelization of straw stems within the indrawn layer due to pass of stems through quite narrow one-side notches of given profile with wavy convex side faces, and transmission of required load on the material through a larger contact area as compared with the smooth rollers. This creates conditions for appearance of many centers of shear load or normal and tangential shearing stresses, which raises effectiveness of breaking and cleaning on the grooved rollers of softening machine.

Fig. 2 shows the node for cleaning of raw material from flax straw of the scutcher. Fig. 3 features a squashing roller of the cleaning node.

The node for cleaning of raw material from flax straw of the scutcher consists of two smooth breaking rollers (*1*), a pair of sharp-grooved breaking rollers (*2*) with a small radius of edge curve and relatively high grooves as compared with their step and two squashing rollers placed between them (*3*). Each squashing roller is a hollow cylinder throughout the length of which there are one-side notches of given profile located circle-wise, at a regular step, and whose wavy convex side faces, with wave of the one side face being between waves of the other face, ensure a steady minimum gap between the profiles of squashing rollers. Further, there are two shallow-grooved breaking rollers (*4*) with a larger radius of edge curve as compared with that of the edge curve of sharp-grooved breaking rollers (*2*) and with a steady gap between the profiles of groove edges and notches of the two shallow-grooved breaking rollers (*4*).

The machine works as follows: the layer of straw stems prepared in the layer-forming machine is fed to the breaking part of scutcher where it is squashed by the pair of smooth breaking rollers (*1*) and supplied to the pair of squashing rollers (*3*). Having passed *1*, the crushed stems arrive at one-side notches of section *3* located circlewise with a regular step along the whole length. The notches have a given profile, its side faces have a steep convex surface, which ensures transversal compression of woody tissue in those parts of the stem which have not been compressed while squeezing through section *1*. This ensures 3D load in confined space and parallelization of stems within the indrawn layer due to pass of stems through very narrow one-side notches of section *3*, the rollers of which are located circlewise with a regular step along the whole length and have a given profile whose side faces are similar to those of the previous section. The required load on the material is transmitted due to increasing the contact area as compared with the pair of smooth breaking rollers *1*. Having passed the pair of squashing rollers (*3*), the stem layer is fed at a constant rate to the pair of shallow-grooved breaking rollers (*4*).

The grooves of the upper shallow-grooved breaking roller (*4*) press the straw stems between the grooves of the lower roller (*4*) creating a 3D load in the confined space, with fibers due to their inherent flexibility easily contouring the grooves of shallow-grooved breaking rollers *4* and remaining integral along the whole length of the stems. The woody tissue of stems is stiff and fragile, which causes appearance of many damage centers and facilitates bending-breaking and separation of fibers from the woody tissue due to fractures on a length lesser than the critical one in the next pairs of sharp-grooved breaking rollers (*2*).

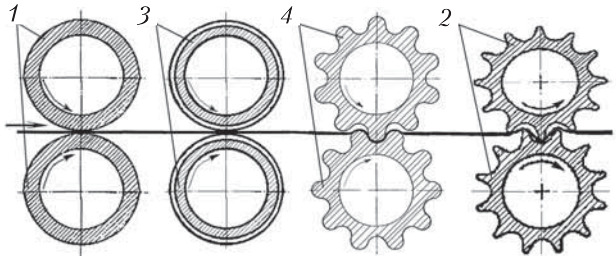

Fig. 2. Node for cleaning of raw material from flax straw of the scutcher

The depth of pass of the grooves of shallow-grooved braking rollers *4* is adjusted in order to create required load on the raw material, without changing the rate of its feed motion. Having passed the shallow-grooved breaking rollers, the layer of raw material is fed forward at a constant rate, to the next pair of sharp-grooved breaking rollers *2*.

The grooves of sharp-grooved breaking rollers *2* are shaped in such a way as the radius of edge curve is small and their height is relatively large as compared with their step. This section *2* performs operations of bending-breaking, sliding bending and separation of fibers from woody tissue of softened raw material with weakened bond of bun and fibers.

The above described node for cleaning of raw material from flax straw of scutcher ensures parallelization of stems in the straw layer, raises effectiveness of breaking, cleaning of raw material, and separation of fibers from woody tissue, which enables further industrial use of the material.

Fig. 4 shows a flowchart of the node for cleaning of raw material from flax straw of the scutcher. Fig. 5 features a squashing roller of the cleaning node. Fig. 6 presents A-A view of the squashing roller.

Figs. 7 and 8 bears an enlarged projection of design of one-side notches of squashing roller with side faces having right- and lift-hand wavy convex profile, respectively.

The node for cleaning the raw material from flax straw of the scutcher in the second option (Fig. 4) has a similar configuration as in the first option (Fig. 2). The only difference is that the

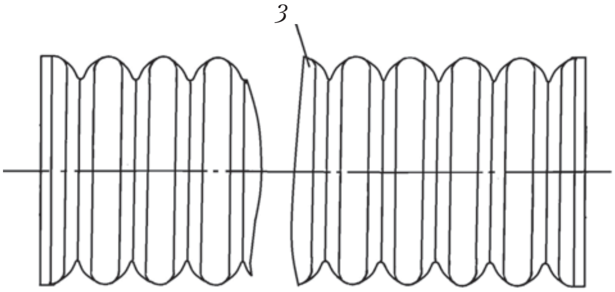

Fig. 3. Squashing roller

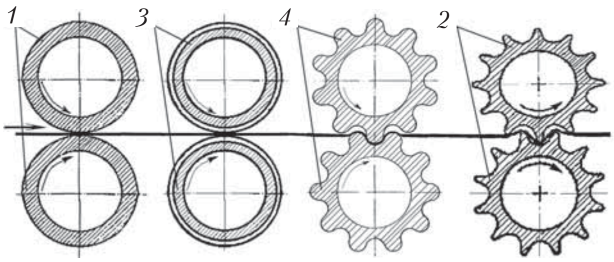

Fig. 4. Node for cleaning of raw material from flax straw of the scutcher

hollow cylinder has one side notches located circle-wise along the whole length. Their profiles wavy convex side faces, with wave of the one side face running between waves of the other face.

The wavy convex side faces ensure a significant transverse compression of stem woody tissue in those parts of the stem, which they have not been compressed when squeezing through the pair of smooth breaking rollers. More intensive compression is achieved due to the wavy profile and 3D load on bast material in confined space. This compression makes the stems of flax straw to lay parallel to each other within the layer indrawn through quite narrow one-side notches of wavy convex profile.

The wavy side faces with waves of the one side running between the ones of the other side ensure bending-breaking, sliding bending and separation of fibers from woody tissue of softened raw material with weakened bond of bun and fibers, and transmission of required load on the material through a larger contact area. This creates conditions for appearance of many centers of shear load or normal and tangential shearing stresses, which raises effectiveness of breaking and cleaning of raw material and separation of fibers from woody tissue in the softening part of machine for processing of raw bast material.

Depending on the type and physical-mechanical properties of raw flax the scutcher can incorporate one or several pairs of mentioned rollers for effective breaking and cleaning of raw material from flax straw.

These nodal elements can be easily introduced into the machinery for primary processing of bast crops designed by the Institute of Bast Crops of the NAAS of Ukraine within the framework of UAAN *Bast Crops* target complex program. Successful combination and introduction of highly efficient technologies for pretreatment of bast crops can address an important economic problem, the resumption of smooth operation of linen and hemp mills and organization of secondary and deep processing of products obtained from these crops.

Each proposed model solves the task by means of relevant configuration changes that improve the mechanical impact of certain aggregate sections on bast raw material. These technical solutions enable to more effectively remove bun and non-fibrous impurities during further mechanical treatment.

The conclusions are based on results of the study carried out at the Staryi Sambir linen mill, the higher is effectiveness of fiber cleaning from woody tissue and other non-fibrous impurities during further mechanical treatment. As a result of this processing the quantity of high quality fibers increases.

Thus, improving design of machine elements provides widening prospects for processing of all types of domestic raw bast materials and increases versatility and efficiency of processing in general. These configuration changes that help improve the quality and increase the quantity of the resulting fiber make it possible to extend the range of products and their use in various industries.

The «green» industry and increasing demand for «bio» production require a wider use of natural flax fiber. To increase its quantities and to improve its quality require advanced technology and new approaches in the treatment of raw bast materials. The implementation of proposed design solutions for domestic light industry makes it possible to develop appropriate innovative products. The resulting flax fiber can be used in the design of a new range of products based on flax-containing materials, which facilitates growing production and sales of «bio» products. However, there is still the need for assessing possible areas of further optimization of technology and use of multipurpose goods based on it, for which high quality of products based on materials with advanced properties and requested configuration are of paramount importance. Therefore, now, this is the most promising direction of development of industrial production. New materials and designs based on flax will enable to develop innovative technologies that provide increased efficiency of production and high quality of «bio» products.

Combining the environmentally friendly properties of flax with the properties of other composite materials in designed products promotes safe consumption and reduces potential environmental contamination as a result of product recycling, which will push the design and production of new range of modern products.

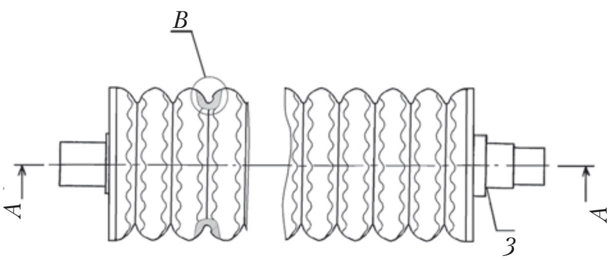

Fig. 5. Squashing roller

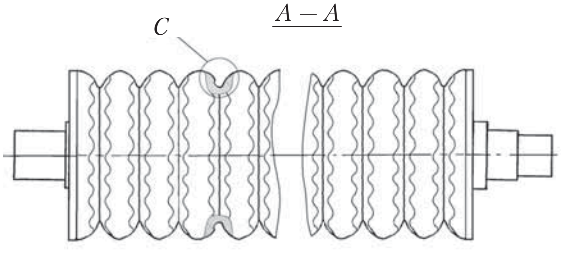

Fig. 6. *A–A* view of the squashing roller

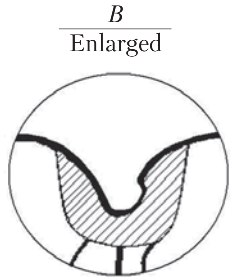

Fig. 7. Notches of squashing roller with right-hand wavy convex profile

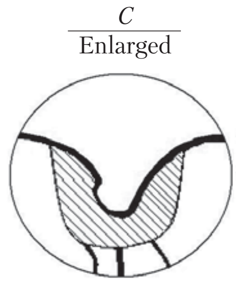

Fig. 8. Notches of squashing roller with left-hand wavy convex profile

The proposed configuration solutions for machining of stem material of bast crops help implement deep processing of flax, which provides the light industry with constantly renewable raw materials. On the other hand, widening the scope of products from natural raw materials is a prerequisite for creating economically favorable conditions in the agricultural sector for the flax cultivation and pretreatment. It enables to preserve and to expand cultivation of flax as a leading technical crop, to guarantee employment of highly skilled workers in rural areas, to reduce dependence on overseas shipments of cotton and wool, even if required funds in foreign currency are available.

In the view of ever rising prices for hydrocarbons and complicated ecological situation in Ukraine, the government needs to develop a trend for designing innovative products of flax-based materials, environmentally friendly groups of textile materials and products manufactured by various techniques for diversified purposes, to lay foundation for and to implement the national market of eco products in order to cooperate with relevant international institutions. This will increase the competitiveness of domestic goods. The proposed technical solutions, including the prospects for modernization of raw flax processing, will enable to create new jobs for able-bodied population in rural regions due to the development of processing industry, in addition to their favorable effect on the light industry and the domestic market of eco products.

CONCLUSIONS

Given the physical wear of domestic machinery and equipment, growing global gross yield of flax, expanding acreage under oilseed flax worldwide and in Ukraine, there is a need to design new equipment and technology for processing of raw flax or to upgrade the existing facilities in order to obtain high-quality flax fiber and versatility of its application. Therefore, now the aim is to find out ways how to upgrade equipment for processing raw bast and to improve the physical and mechanical properties of the product. The producers are focused on searching for innovative products that are competitive in national and international markets and on technology for their manufacture.

The proposed configurations of nodes for cleaning of raw material of the scutcher are promising in terms of improving industrial processing of raw flax and, if commercialized, can facilitate obtaining the fiber with improved physical and mechanical properties, which directly effects the economic status of processing enterprises and raises effectiveness of labor resources in poorly developed regions. Hence, the government shall create necessary conditions for commercialization of these developments that stimulate escalating manufacture of innovative products.

It is necessary to carefully study the changes in physical and mechanical properties of fibers in the course of processing of flax stem material and their dependence on configuration modifications and to develop a respective model for prediction of parameters of final products. This will be the framework for developing proposals on their commercialization.

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ТЕХНІЧНІ РІШЕННЯ ПРОЦЕСУ ПЕРЕРОБКИ ЛЛЯНОЇ СИРОВИНИ

Охарактеризовано теорію та практику технічного переобладнання підприємств з переробки лляної сировини, модернізацію виробництва, використання сучасних технологій і устаткування. У статті проаналізовано результати моделювання процесу очищення лляних волокон від неволокнистих домішок, які виконували для різних параметрів та конфігурацій обладнання. Доведено можливість і доцільність застосування нововведень для підвищення фізико-механічних показників якості лляної сировини. Вказано підстави розвитку переробної промисловості України та отримання позитивних результатів з обробки стеблового матеріалу льону через використання інноваційних технологій переробки, прогресивних технічних рішень та оригінальних прийомів обробки новими пристроями.

Ключові слова: волокно, льон, сировина, якість, очищення, переробка, обладнання, виробництво.

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ТЕХНИЧЕСКИЕ РЕШЕНИЯ ПРОЦЕССА ПЕРЕРАБОТКИ ЛЬНЯНОГО СЫРЬЯ

Охарактеризовано теорию и практику технического переоснащения предприятий по переработке льняного сырья, модернизацию производства, применения современных технологий и оборудования. В статье проанализированы результаты моделирования процесса очистки льняных волокон от неволокнистых примесей. Представлено воспроизведение процесса очистки для различных параметров и конфигураций оборудования. На основе проведенных исследований доказана возможность и целесообразность применения нововведений для повышения физико-механических показателей качества льняного сырья. Выяснено основания развития перерабатывающей промышленности Украины для достижения положительных результатов по обработке стеблевого материала льна через использование инновационных технологий переработки, прогрессивных технических решений и оригинальных приемов обработки новыми устройствами.

Ключевые слова: волокно, лен, сырье, качество, очистка, переработка, оборудование, производство.