

DEVELOPMENT OF INNOVATIVE TECHNOLOGIES SCIENTIFIC FOUNDATIONS FOR PRODUCING BEST FIBERS FOR SPECIAL PURPOSES

РАЗРАБОТКА НАУЧНЫХ ОСНОВ ИННОВАЦИОННЫХ ТЕХНОЛОГИЙ ДЛЯ ПОЛУЧЕНИЯ ЛУБЯНЫХ ВОЛОКОН ЦЕЛЕВОГО НАЗНАЧЕНИЯ

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ABSTRACT

The present work contains the results of theoretical and experimental studies aimed at developing technologies for producing bast fibre retted straw to produce cellulosic semi-finished products in order to expand the scope of oilseed flax fibre in the production of cellulosic consumer goods. It is theoretically and experimentally proved based on comparative studies of the structure and chemical composition of flax stems and hemp, the necessity to create a new technology for the mechanical processing of these crops for the production of fibre with the given qualitative indices.

РЕЗЮМЕ

Представленная работа посвящена развитию научных основ инновационных технологий получения лубяных волокон пригодных для дальнейшей химической переработки и использования его в различных отраслях промышленности. Теоретически обосновано и экспериментально доказано на базе сравнительных исследований строения и химического состава стеблей льна и конопли необходимость создания новой технологии механической переработки этих культур для получения волокна с заданными качественными показателями. На основе установленного механизма штапелирования, выделение костры и разволокнения технических лубяных пучков предложены новые способы обработки стеблей, основанные на процессах управляемого измельчения и очистки, которые способствуют разрушению целостности стеблей и повышению степени разволокнения.

INTRODUCTION

Today, the pulp and paper industry in the world has prospects for development, but it also needs to solve important problems that must be addressed differently in different types of countries (Kocharov S.A. et al., 2002, Vurasco A.V. et al. 2006). Among the numerous problems in the pulp and paper industry of Ukraine, we can distinguish the main one - the search and use of alternative sources of raw materials. The main reason for this problem, which holds back the further development of the pulp and paper industry, is the absence in Ukraine of its own production of primary semi-finished products (Tihosova A.A. et al., 2010, Lyalina N.P. 2015). Thus, the growing shortage of wood raw materials and large foreign exchange costs for the purchase of cellulose abroad make it advisable to use cellulosic materials, in particular, existing bay crops in Ukraine.

It is known that one-year non-woody plants have a high content of cellulose and are widely used both for the production of fabrics and for the production of fibrous semi-finished products intended for the manufacture of cellulosic materials (Myenyaylo-Basistaya I.A. 2013). In many countries of the world, for example in Pakistan, Thailand and Peru, non-hardwood raw materials are the main type of raw material for the production of cellulose. In China, almost 87% of cellulosic products are produced from straw perennials.

Therefore, the manufacture of cellulosic products in Ukraine may be subject to the use of domestic raw materials (hemp and flax), innovative scientifically based technologies for the cultivation and processing of natural fibrous raw materials, increase of investment attractiveness of industrial segments, which will use natural raw materials and coordinated action programs in their products with the government and scientists.

MATERIALS AND METHODS

Materials

According to the prototype, hemp stems of the spring collection, varieties of textile, Victoria, Glance and Nick, were grown in Ukraine. Experimental researches were conducted with varieties of oil flax: Debut, Southern Night and Vira.

Modernized technological process of bast fibres processing

On the basis of the established stapling mechanism, isolation of chaff and garneting of technical bast bunches, new methods of stems processing, based on the processes of controlled crushing and purification, which contribute to the destruction of stems integrity and increase the degree of garneting level, have been proposed.

It was established that the increase in crushing bast fibre complexes at enhancing speed interaction of chopping rollers with the layer of processed material is more intense than with the increase in the number of mechanical actions. In connection with this, forcing the crushing process of technical complexes of bast fibres is more expedient to implement not by increasing the number of mechanical actions, but by increasing the speed of interaction between rasp-bar threshing rollers and fibre strand (*Gilyazetdinov R.N. 2009*).

The composition of the technological line for the production of purified staple fibre from bast crops and the replacement of typical threshing and breaking machines and tow scutcher with the modernized tow scutcher, which includes chopping rollers, is theoretically substantiated.

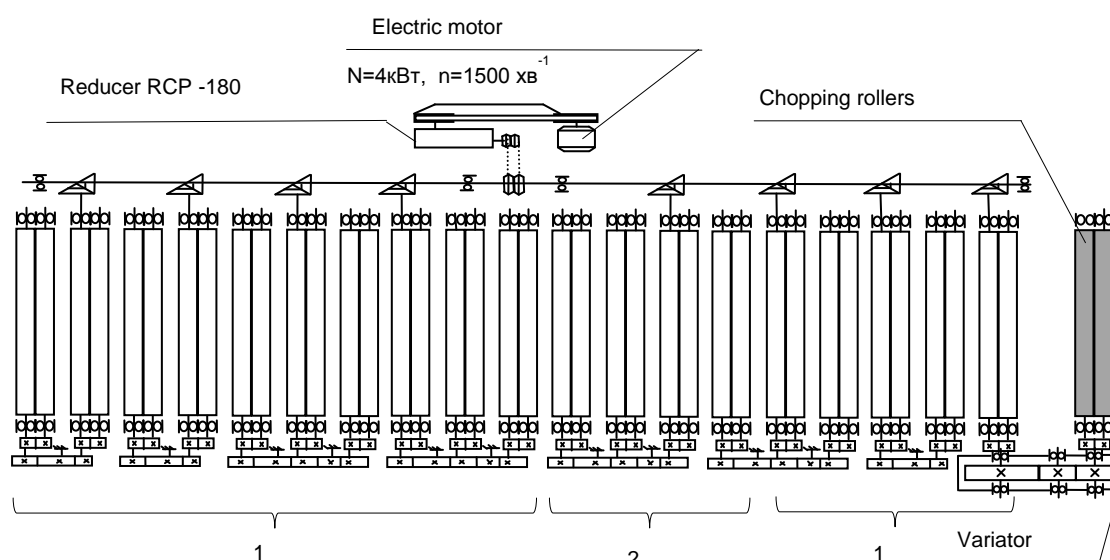


Fig 1 - Kinematic scheme of the experimental installation:

1 - rolls of direct corrugation, 2 - rollers of screw corrosion

The melting part of the plant is driven by an individual electric motor, from which, through a wedge-shift transmission, a worm gear unit RCP-180 and a dual chain drive, two longitudinal shafts receive a rotating moment, which, by means of conical gears, rotate to the lower roller rollers. The velocity of the material being processed in it is 22.4 m/min.

Full-featured installation

To determine the optimal parameters of cleaning plant operation, a full-featured experiment was conducted, in which the staple composition of fibre became an assessment criterion.

The study of mechanical processes theoretical foundations of cleaning and garneting the bast raw materials has shown that due to the differentiation of the conditions of drawing the layer of feedstock and regulating the entering depth, the rotation speed and the grooves step during breaking, it is possible to intensify the separation process of the wood from the fibrous part of the stem.

For bast fibre crushing, it is necessary to change the differentiation conditions of breaking in the last pair of mechanical rollers due to toothed cohesion and regulation of rotation relative speed, which allows to simulate the process of scutching and stapling on the threshing machine. It is also necessary to provide controlled crushing of broken raw products due to the increase of the processing intensity generated by the introduction of additional forces in the breaking process that characterize threshing process.

For thinning the fibre complexes, it is the most efficient to use devices that provide additional scutching of restrained fibre strand (Novikov E.V. et al., 2014). These devices, in conjunction with additional cleaning plants, should provide a sufficient degree of purification. In order to select rational regimes and parameters of purification, the process of impact interaction of movable operating element with fibre was studied and a model of interaction of roll flute edge with a separable part of chaff and fibre was developed. The analysis of the model showed that the movement of chaff part with fibre strand is influenced, at first, by the speed of roll flute rotation and the frequency of its operations.

The method for determining the impact load on fibre strand, which allows choosing the most rational technological and structural parameters of the installation and process, is proposed.

The impact load on the fibre strand was calculated and a linear model of the impact interaction process of fibre strands with roll flute element was developed.

The analysis of this model and its comparison with experimental data allowed us to establish that fibre strand should be considered as an elastic element that has a restricted mass. Application of the model during the design of equipment for the production and cleaning of short-staple bast fibres will make it possible to determine the rational parameters of equipment and technological process more accurately.

As a result of theoretical study, a nonlinear model of the impact interaction process of fibre strands with roll flute element is created. A methodology that allows estimating nonlinearity of stiffness characteristics of fibre strands on the basis of experimental research results is suggested. The method of calculating the parameters of the impact interaction process is presented. The developed model more fully describes the impact interaction process of fibre strands with movable operating element than linear models.

Increase of bast fibre crushing is characterized by a classic curve of damage accumulation and consists of three stages: the stage of intense damage accumulation, the stage of moderate damage accumulation, the stage of critical destruction.

A new method for determining the physical and mechanical characteristics of staple bast fibres is proposed, based on modern methods of mathematical data processing in the software environment "MATLAB 7.0" (Ostapchuk M.V., et al., 2006).

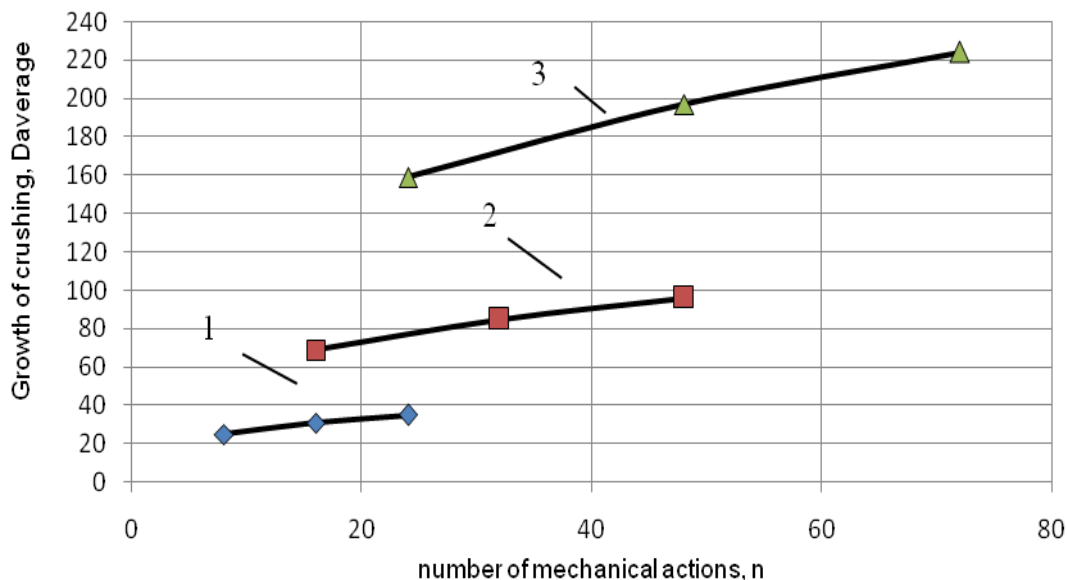


Fig 2- Dependences of the growth of linen complexes fragmentation on the number of mechanical actions at the interaction rate:

1 – 48,98 min^{-1} ; 2 – 97,99 min^{-1} ; 3 – 146,95 min^{-1}

On the basis of the dynamic analysis of fiber strands interaction, which contains the separable part of chaff, with the movable operating element it is shown that the efficiency of garbage impurity extraction during the impact will be increased as the fiber line decomposes, when the mass of wisps of fibers interacting with the movable operating element will come nearer to the mass of separable fibrous parts of chaff.

It was established that the increase in crushing bast fiber complexes with increasing the interaction speed is more intense than with increasing the number of mechanical actions. Consequently, the intensification of bast fiber complexes crushing process is more expedient to implement not by increasing the number of mechanical actions, but by increasing the interaction speed.

The proposed technology is based on the use of inertial fiber cleanser

The study of theoretical foundations of cleaning and garnetting mechanical processes of bast raw materials has shown that due to the differentiation of the conditions of drawing the layer of feedstock and regulating the entering depth, the rotation speed and the grooves step during passing, it is possible to intensify the separation process of the wood from the fibrous part of the stem (Virovets V.G., et al., 2011).

The conducted experimental researches have shown the advantages of the proposed technology, which affirms the expediency of using a fiber cleanser for cleaning and garnetting the technical bast complexes. The optimum values of the nutrient layer density and the rate of its delivery for providing high quality bast fibers obtained on the fiber cleaner have been determined. In addition, crushing of contaminated impurities, which facilitate their easier removal during further processing takes place in pre-treatment process.

Based on the developed mathematical model, the influence of raw materials characteristics and the technological equipment structural specifications on the final qualitative characteristics of the linen fiber was investigated, as well as the most rational modes and parameters of the fiber cleaner operation were selected.

The technological line proposed is based on the use of the modernized breaking part of the tow scutcher unit KPAL and is intended for the mechanical preparation of bast raw materials for further chemical treatment through the use of chipping rollers and additional purification of crushed stalks on a fibercleaner and a fiber-separating machine BOM-2.

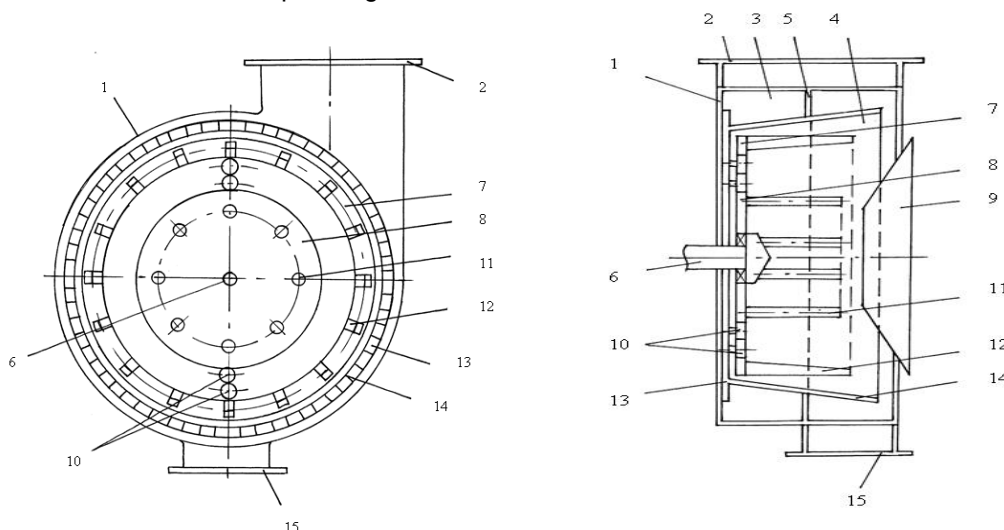


Fig 3 - Fiber cleanser scheme

1 - body; 2 - outlet pipe; 3 - the burning part; 4 - fiber-separating part; 5 - separator; 6 - shaft; 7 - external rotating disk; 8 - internal rotating disk; 9 - diffuser loader; 10 - toothed pair; 11 - white rods; 12 - comb; 13 - grate grating; 14 - rods; 15 - outlet pipe

Fibrous processing complexes are not strictly fixed and the process of bonnet separation is intensified by means of centrifugal forces that arise due to the beating rods rotation. In addition, the speed of the external disk drive exceeds the speed of the inner one, creating the effect of additional stretching. Due to the proposed changes in mechanical action, a more efficient cleaning of flaxseed from the derivative (Table 1) is carried out.

Table 1

Variations of the main structural and technological parameters of the fibre cleanser

Variable parameters of working bodies	Numbers of comb combinations							
	1	2	3	4	5	6	7	8
Step of comb fins, mm, (X ₁)	120	120	120	150	150	150	120	150
Angle of inclination of comb, degree, (X ₂)	55	55	45	55	55	45	45	45
Width of comb ribs, mm (X ₂)	100	150	150	100	150	150	100	100

According to the results of theoretical and experimental researches, an innovative technology of bast crops primary processing, which has undergone extensive testing in scientific circles and has found positive feedback from industry experts, has been proposed.

Mathematical description of the technology of stapling and cleaning bast fibers during their processing on the proposed equipment allowed establishing a number of experimental and theoretical dependencies that determine the boundary values of the adjustment parameters of technological equipment separate units and the process of bast crops mechanical treatment in general, which will allow to create an innovative technology for the production of bast fibers for various industries in Ukraine.

RESULTS

On the basis of the conducted research complex the scientific concept of equipment improvement for the innovative technologies of bast crops primary processing has been developed, which ensures the production of bast fibers of the intended purpose. On this ground for the first time:

- it is proposed to use chopping rolls in mechanical processing of bast stems with the aim of intensifying the process of obtaining cellulosic raw material;
- scientific development was given to production theoretical foundations of various intended purpose bast fibers, based on implementing modern technologies for complex mechanical processing of flax stems and hemp;
- a new concept of bast stems mechanical processing is theoretically grounded, based on the garnetting of technical fibers complexes due to the use of new mechanical actions in the initial stages of raw materials primary processing;
- the model of the crushing process of bast fiber complexes has been developed, which made it possible to establish that the increase in crushing of their complexes with increasing interaction speed is much more intense than with increasing the number of mechanical actions;
- the methodology of determining qualitative parameters of bast fibers on the basis of mathematical data processing on the input characteristics of bast crop stems, structural features of the equipment, parameters and modes of mechanical processing has been developed;
- the criterial evaluation methodology of structural parameters of bast crops staple fiber, which will determine its functional purpose has been developed.

As a result, from obtained hemp fiber cellulose, paper was obtained, the qualitative parameters of which are presented in Table 2.

Table 2

Qualitative characteristics of paper obtained from hemp fiber

Quality score name	Quality score value		Divergence $\pm\Delta$
	by standard	received paper	
Weight of paper with an area of 1m ² , g	75,0	97,0	-22,0
Air permeability, at $\Delta p=200$ Pa, $S=10$ sm ² , l/m ² sec	830	1350	+520
Absolute resistance to dampening, kPa	0,45	0,60	+0,15
Destructive effort, kN / m	2,0	4,5	+2,5
Thickness, mm	0,6	0,8	-0,2

The use of bast crops stems to obtain cellulose materials for various purposes will contribute to a significant reduction of environmental damage from deforestation, eliminate the import dependence of Ukraine in the manufacturing of strategically important products, and an increase in the production of polymeric materials, reinforced with natural vegetable fibres, will provide lower prices for cars, will stimulate the development of farms, reduce soil contamination and improve the composition of the air.

In order to create innovative technologies for the production of bast fibers, practical recommendations for increasing the efficiency of their further chemical treatment, which are aimed at obtaining high-quality fibrous semi-finished products and determining the degree of their suitability for the use in various spheres of industrial production have been developed (*Popadinets N.M., 2011*).

CONCLUSIONS

The theoretical laws and regulations, formulated by the author, are the basis of a new methodology for the creation of both individual processes and the whole technology of bast crops complex processing.

The results of experimental studies indicate that obtaining high-yielding cellulose from flaxseed may be at a temperature of 160-170° C, boiling time of 180-300 minutes, and concentration of NaOH boiling solution of 30-40 g / l.

Boiling of flax straw untreated stems by the sodium carbonate method makes it possible to increase the yield of cellulose from 60.1% to 90.0%.

If short flax fiber is used as raw material, high yield cellulose can be obtained at a boiling temperature of 170 to 160°C, at boiling time of 180-300 minutes, and concentration of NaON boiling solution of 45-50 g/1.

The analysis of the experimental data obtained shows that, with practically the same strength, the air permeability in paper samples obtained according to the proposed technology is three times higher than the existing standards.

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