RESEARCH OF THE DYNAMIC MODEL OF THE FLAX STEMS LINE ARRANGING MECHANISM
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ДОСЛІДЖЕННЯ ДИНАМІЧНОЇ МОДЕЛІ МЕХАНІЗМУ ПІДБИВАННЯ СТРІЧКИ СТЕБЕЛ ЛЬОНУ-ДОВГУНЦЯ

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ABSTRACT
The article deals with the dynamics of mechanism for arranging the flax stems line on the conveyor belt. There were developed the equations of the kinematic pair which is included as a compound of mechanism. The equation for calculating the conveyor belt length was developed.

РЕЗЮМЕ
У статті розглянуто динаміку механізму підбивання стебел стрічки льону, яка поступає на транспортер підбирача стрічок льону-довгунця. Виведені рівняння для опису динаміки кінематичної пари, яка входить до складу механізму підбивання та отримано вираз для визначення довжини транспортеру стрічок.

INTRODUCTION
Flax is traditionally grown in Ukraine and it provides a lot of benefit. People use flax fiber, seeds and by-products. The flax fiber is used to produce highly persistent household or technical clothes. Flaxseed oil is used in food industry as well as for technical aims (to produce varnishes, oil paints and lacquers) and for electrical, pharmaceutical, rubber and leather production. The value of flax fiber is higher than the value of other fiber plans, such as cotton, hemp, kenaph. Flax fiber is healthy, nice and putrefaction resistant; it has taken on market all over the world. Flax press cake with around 36% of protein is used in farm industry as animal feeding stuff. Flax by-products (oakum, shove) serve as source for paper and building material production.

The areas of flax plantings have been decreased recently. In 1990 there were 172 500,00 hectare of them, but in the following years these areas became smaller because of various reasons; in 2015 there were 1, 91 thousand hectare *(Statistical bulletin, 2015)*.

Flax cultivation should be renewed in Ukraine. A lot of measures are necessary to raise the amount of flax production.

Taking into consideration all above, we formulate the task for the flax industry – development of modern technologies of growing, cropping and manufacturing of flax in order to increase the quality and decrease the wastes. Ukrainian agriculture will need more machines for flax cultivation and cropping if the areas of flax plantings increase. It is especially important to mechanize the flax cropping process because it is labour-consuming.

The researches of Ukrainian and Russian scientists *(Nalobina O.O., 2004;* Nalobina O.O., Gerasimchuk O.P., 2014; *Nalobina O.O. and Muravynets Y.V., 2012; Nalobina O.O., Puts V.S., 2013;* Zincov O.N., 2016*)* have proved that the index of the length of flax stem line influences the final product of flax industry. This index is formed in several stages: during flax taking, transporting by the combine working tool, while making a line, lying, making retted straw.

The analyses of exciting research has shown that one of the possible ways to reduce the flax line length is to introduce the operation of arranging the stems in the line either during cropping or unrolling at the stage of primary machining. It is necessary to have special piling (arranging) mechanisms to perform this operation. Some works *(Chernikov V.H., Rostovtsev R.A., Konokhov V.J, 2004; Chernikov V.H., Rostovtsev R.A., 2005; Konokhov V.J, 2004; Nalobina O.O., Puts V.S.,* Tolstushko N.N., 2014; Rostovtsev R.A., Konokhov V.Y., 2006; Zincov O.N., 2007*)* research these mechanisms. The authors suggest reducing the line length by affecting the stems with different mechanisms, but they haven't taken into consideration the fact that the stems in the line are usually intertwisted.

They researched parallel and not intertwisted stems that don't correspond to reality.

The authors of this work got a technical task to provide the arranging of flax stem line where the stems may be intertwisted and lopsided; they have constructionally completed this task.

In order to complete the above mentioned task, they have performed the system research that allowed to analyze the behaviour of the complex physical system consisting of data sets, technical and plant components. It is well-known that system research involves performing two tasks – analyses and synthesis *(Sydorchuk O.V., Nalobina O.O., Demyduk N. A. et al., 2011)*. We have analyzed the system that consists of flax cropping machines and the plants of flax, this system works under the influence of various external and internal factors *(Hylleys H.A., Konovaliuk D.M., 1992; Nalobina O.O., 2012)*.

The authors have discovered that cropping of the vertical flax stems by combines gives the high index of flax straw quality. However, the experience of harvest works in different regions of Ukraine, Belorussia and other countries has shown some drawbacks of combines: great length of flax stem line, parallel misalignment, damages; these defects can be eliminated due to the improvement of design parameters of flax cropping machines.

This article presents the results of theoretical work aimed to perform the systemic syntheses and as result the authors have made the real model of the apparatus for arranging the flax stem line; it allowed to research the working dynamics of the arranging mechanism *(Hylleys H.A., Nalobina O.O. et al. 2001)*; this mechanism helps to make the stem flax line smaller, arrange the flax stems in parallel.

MATERIAL AND METHODS

The work presents the research based on the principles of theoretic mechanics and kinetics of material systems. Figure 1 shows the scheme of the apparatus for arranging the flax stem line.

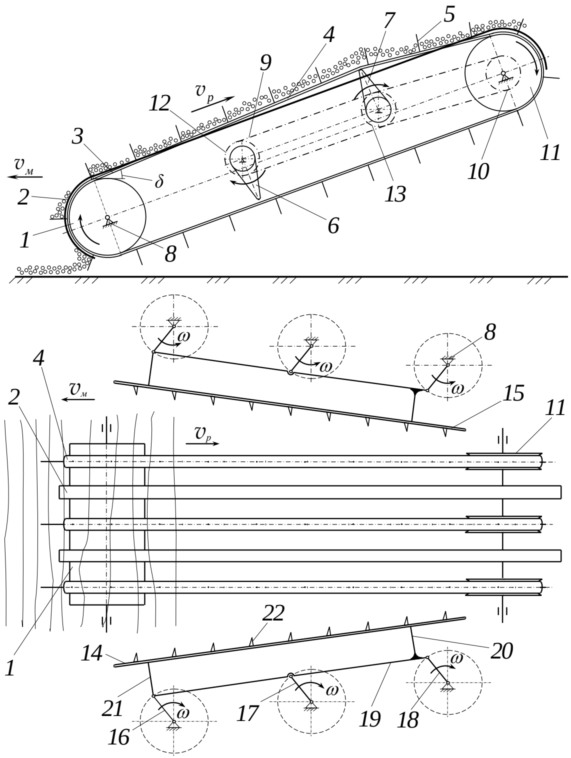

Fig. 1 - Scheme of the apparatus for flax stems arranging

1 – drum, 2 – guideway, 3 – conveyor, 4 – conveyor belt, 5 – pin, 6,7 – jaws, 8 – frame, 9 – chain, 10 – drive sprocket, 11 – shaft, 12, 13 – driven sprockets, 14, 15 – crash protectors, 16, 17, 18 – crank shafts, 19 – piston rod, 20, 21 – planks, 22 – ribs.

The apparatus consists of two mechanisms: shaking mechanism and piling mechanism. The shaking mechanism consists of the jaws *6, 7* and the drive gear made of the chain *9*, the drive sprocket *10* fixed to the drive pulley of the shaft *11*, the driven sprocket *12* with the jaw *6* fixed to the shaft, the transition sprocket *13* fixed to the same shaft that the jaw *7*. On the both sides of the conveyor the two crash protectors *14* and

15 are symmetrically situated, they are the parallel link motions consisting of the crank shafts 16, 17, 18 and the piston-rod *19* with the adjustable spring plank *20* at one of its edge.

The same spring plank *21* is fixed to the edge of another piston-rod by linkage joint. The plank height is regulated with the nut. Each plank contains the spring hidden inside the pinion carrier. The planks *20, 21* from the other side are fixed to the ribbed crash protectors *14, 15* by linkage joints. The mechanisms are installed within the frame and they are driven with the shaft offtake from the tractor.

Figure 1 shows the arranging system of the conveyor that includes the drum *1*, guideways *2*, conveyor *3*, continuous belts *4* with the pins fixed on them.

In order to increase the arranging effectiveness, the conveyor that runs on the belts *4* and guideways *2*, is shaken periodically. The stems are tossed and separated, that is why the crash protectors can arrange them easier. The tossing is caused by the sequential jaws kicks upon the upper conveyor track. The arrangement of the flax line starts in the A-A zone (fig. 1) and finishes in zone B-B.

Pilling transporter and arranging apparatus are in the harvesting unit in front of the press or tying device, and the drum is situated in front of the stem line. This part of the machine should be under the machine operator's control all the time. The center conveyor slot should function in the conveyor belt zone where the stem centers are situated.

The jaw (figure 2) rotates with the rotational velocity around the axle in order to shake the conveyor belt. The axle can change the position due to the spring plank variations.

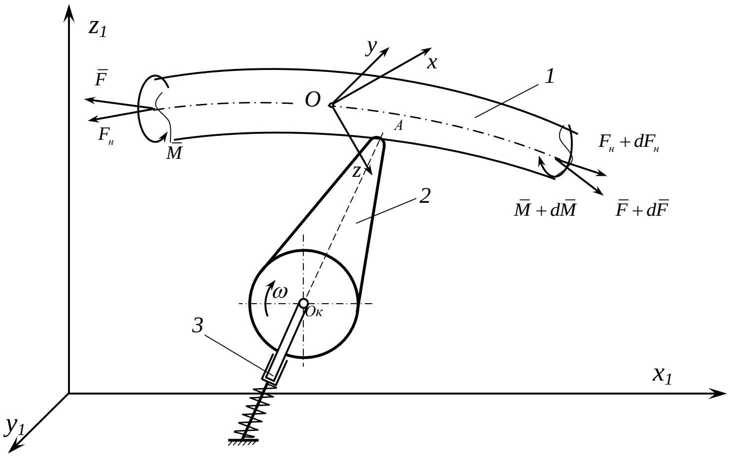

Fig. 2 - Dynamic model of the kinematic pair: conveyor belt – jaw outer surface

1 – belt, 2 – jaw, 3 – adjustable spring plank

The point on the jaw outer surface moves with the speed $V = O_к A \cdot \omega$ in the moment when it touches the conveyor belt, where $O_к A$ is the distance between the jaw rotation centre and the point on the jaw outer surface touching the conveyor belt in the moment. When the jaw surface moves along the belt, it turns to the angle $\alpha = \omega t$, where *t* is time, sec.

Figure 2 shows the element of the conveyor track of the flax line, which is influenced by the forces: *F* – cross-axle force and stretching force F_H, *M* – bending moment that appears under the jaw action in the surface element of the conveyor: $M = EI/r$, where *r* – radius of belt bending due to the contact with the jaw, *E* – power module of belt material, I - inertia moment. The moment can cause slight displacement of the conveyor belt. However, the moment will not have the considerable influence of the conveyor work if the belt tension is correct. The belt bents and becomes longer under the influence of the jaw. The belt prolongation is calculated *(Svetlitskii V.A., Stasenko I.V., 1994)*.

$$\Delta l = r_d \beta_1 - r_s \beta_2 \tag{1}$$

r_d, r_s - are radiuses of the drum and shaft (drawing 1), [m];

β_1, β_2 - deviation from equilibrium of the corresponding belt areas, [grad].

RESULTS

Let's assume that the belt moves with the speed *V*, m/s; resulting force of *F* and F_H is *R*; the length of belt element under the influence is *l*, m.

Thus, we can write the equation of belt movement on jaw outer surface with forces on the axel ZYX (fig.2):

$$\left.\begin{aligned} m_n \frac{dV}{dt} - m_n V_{z_1} \omega_{y_1} = \frac{\partial R_z}{\partial x} - \frac{R_z}{r} + \frac{T_x}{l}, \\ m_n \frac{dV_z}{dt} - m_n V \omega_{y_1} = \frac{\partial R_z}{\partial x} + \frac{R_x}{r} + \frac{T_z}{l}, \end{aligned}\right\}, \tag{2}$$

m_n – belt weigh, [kg];

T – jaw tension on the belt, [mPa].

The speed of the belt element moving in a certain moment directly on the jaw outer surface will be different from V_A, because of deformation and fluctuation. Taking the fluctuations into account, we can assume that they will cause some slight shifts of equilibrium: *s* and s_z. Considering this, we will substitute expression in the equation (2):

$$\left.\begin{aligned} V = \frac{\partial s}{\partial t}, \\ V = \frac{\partial s_z}{\partial t}. \end{aligned}\right\}, \tag{3}$$

The jaws rotates with the speed ω. There should be a contact between the pin in the outer surface of the jaw and the inner surface of the conveyor belt to shake the conveyor belt and, correspondingly, the flax stem line. In order to assure this condition the distance from the rotation centre of the jaw to the conveyor belt in the moment when the pin A neither touches the belt nor deforms it should be chosen with regard to the following condition:

$$h = O_\kappa A - \Delta, \tag{4}$$

Δ is the spring deformation in the moment when the curve of the jaw nut rises the belt to the highest position (fig.2), [mm].

The flax stems will be torn from the ground if they get acceleration $a = \frac{dV}{dt}$ from the jaw hit.

Thus, the speed of the conveyor belt transport *V* must be higher than the product $V_{C_1} tg\delta$, where V_{C_1} is the initial speed of the stems and the conveyor surface in the moment when the nut of the jaw touches them, δ is the bending angle of the conveyor belt (fig.1).

The bending angle of the conveyor upper track δ respective the horizon equals: $\arcsin \frac{H}{L}$, where *H* is the stem line height, *L* is the distance that the stems pass, and they are risen *κ* times by the jaws.

In order to reason the belt length L_b we assume that minimal required distance between the axels of the drum and the drive pulley is L_{min}.

Thus, the minimum conveyor length is calculated

$$L_{b\min} = L_{\min} + r_d + r_s \ , \tag{5}$$

where $L_{\min} = \kappa n$ here *κ* – number of jaws, *n* is distance between them.

CONCLUSIONS

The authors have constructed flax stem line arranging mechanism that allows reducing the length of the flax stem line or flax stem roll during cultivating.

The authors have specified efficient elements of this machine taking into consideration the stems tearing from the conveyor belt, the differential equation (2) of dynamic pair jaw-belt, and the equation (5) and the design of the flax stem pickup with arranging mechanism.

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