# CHECKING PERFORMANCE OF DISC-BELT FLAX PULLING APPARATUS

**Serhii Yukhymchuk, Svitlana Yukhymchuk, Mykola Tolstushko, Nataliya Tolstushko**
Lutsk National Technical University, Ukraine
sergei-71@ukr.net, s.yukhymchuk@lutsk-ntu.com.ua,
tmmtno@gmail.com, nataleksa1978@gmail.com

**Abstract.** Pulling devices are used to pull flax stalks from the soil during mechanized harvesting of fibre flax. Some of them are belt and belt-disc pulling devices, in which the pulling belts, which work as belt transmissions, stretch during operation and require periodic tightening, and replacement when worn. In addition, this design of pulling apparatuses is too material-intensive. This is due to the use of pulleys, tension and support rollers, complex drive. We offer a new design of the disc-belt pulling apparatus. In it, the drive is carried out directly on the pulling discs, and the pulling belts press the flax stalks to the surface of the pulling discs. That is, the belt does not transmit the torque from the driving to the driven pulleys, which means that it stretches less during operation. The pulling assembly contains fewer parts, so the proposed disk-belt flax pulling apparatus is less material-intensive compared to analogues. The patented design of the disc-belt flax pulling apparatus will increase the durability of the gleaning belts and reduce the material capacity of the flax gleaning machine. An experimental installation was made and its operability was tested in field conditions. The influence of the speed mode indicator (the ratio of the forward speed of the installation across the field to the circular speed of rotation of the pulling disk) of the disc-belt pulling apparatus on the purity of pulling and seed loss was determined. The results of the experimental studies confirmed the workability of the proposed design of the disc-belt pulling section. It was established that with an increase in the speed mode indicator from 0.5 to 1, the purity of pulling flax stalks changed from 99.7% to 98.8%, and the loss of seeds – from 0.7% to 2.0%. This gives reason to assert that the pulling apparatus meets the agrotechnical requirements for flax-harvesting equipment.

**Keywords:** flax, stalk, pulling, disc-belt flax pulling apparatus.

## Introduction

In the world, there is a trend towards an increase in the demand for natural fibers, in particular, those obtained from flax. This is explained by the expansion of the scope of application of natural fibers due to the creation of new types of products based on them. Flax fiber production waste has also found wide application. Fuel briquettes, peat-based fertilizers and materials used in the construction and furniture industry are made from flax firewood. Flax seeds are used in the food, pharmaceutical, paint and perfume industries. Seed processing waste - cake and meal - is used in fodder production [1; 2].

The complex of flax harvesting operations begins with pulling, i.e. pulling the stalks out of the soil by the working bodies of the flax harvesting machines. Flax whole stem is pulled out of the soil and the productive part of the stem, which contains fiber, is not lost with the stubble, which occurs during mowing (cutting) of flax. When the streams of stalks are combined at the exit from the pulling devices, a ribbon of flax stalks is formed. All subsequent technological operations carried out on flax stalks in the field and during primary processing up to the separation of the fiber are carried out on the stalks in the tape. That is why pulling flax and forming a ribbon is a technological operation where the parameters of the flax ribbon create the conditions for the efficient course of all subsequent technological operations [3; 4].

Therefore, the design of the pulling device should also ensure high productivity of the flax harvesting unit (speed of movement of the unit through the field) with the necessary purity of pulling and the formation of a flax ribbon with parameters that meet agrotechnical requirements.

To pull the stalks of flax from the soil during mechanized harvesting of flax belt and belt-disc pulling apparatus are used [5].

In belt pulling apparatuses, the stalks are clamped between two pulling belts, which work as belt transmissions, in which the working branch is tensioned. The belt covers the drive and driven pulleys, or the drive pulley and tension rollers.

In belt-disc pulling apparatuses, flax stalks are clamped between the pulling belt and the pulling disc. At the same time, the pulling disk rotates from contact with the pulling belt. That is, the belt is even more loaded than in the belt pulling apparatus.

Pulling belts are made of rubber reinforced with kapron threads and in the process of work are stretched and need to be periodically tightened, and when worn, they need to be replaced.

In addition, these designs of pulling apparatuses are quite material-intensive. This is due to the use of pulleys, tension and support rollers, complex drive.

Therefore, it is relevant to develop such a design of the pulling apparatus, which would eliminate these shortcomings.

## Materials and methods

We offer a new design [6; 7] of the disc-belt pulling apparatus. In it, the drive is carried out directly on the pulling discs, and the belts press the flax stalks to the surface of the pulling discs. That is, the belt does not transmit torque from the driving to the driven pulleys, which means that it stretches less during operation.

The pulling apparatus is tilted at an angle to the horizon.

Fig. 1 schematically shows the proposed disc-belt flax pulling apparatus.

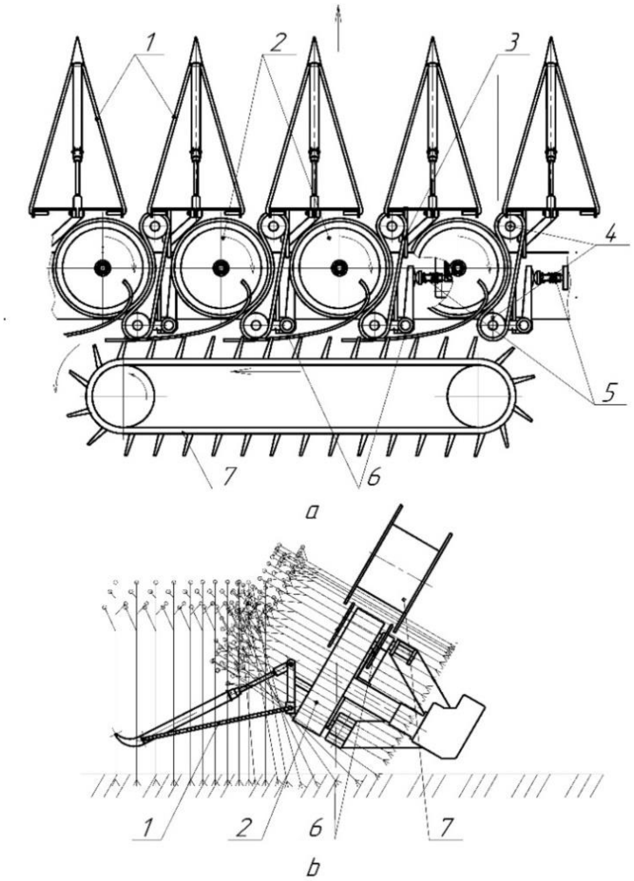


Fig. 1. **Disc-belt flax pulling apparatus:** 1 – dividers; 2 – pulling discs; 3 – pulling belts; 4 – rollers; 5 – spring–loaded fasteners; 6 – guide bars; 7 – transverse conveyor; a – top view; b – side view

The disc-belt flax pulling apparatus includes: a prefabricated frame (not shown in the figure); dividers 1, pulling unit, which includes pulling disks 2, pulling belts 3, rollers 4, spring-loaded fasteners 5, guide bars 6, transverse conveyor 7.

The disc-belt flax pulling apparatus works as follows.

The drive of the pulling discs, which rotate in the same direction, is carried out from the frame crankcase. On the one hand, each pulling disk 2 is covered by a pulling belt 3, which is put on rollers 4. Due to the spring-loaded fastening 5 of the upper roller 4, constant tension of the pulling belt 3 is ensured, which means pressure in the pulling stream.

When the machine moves along the surface of the field, the dividers 1 divide the flax stalks into separate strips and direct them to the mouths of the pulling streams. Further, the flax stalks are clamped between the contacting surfaces of the pulling discs 2 and pulling belts 3, pulled out of the ground and moved to the exit from the pulling streams, where they are captured by the fingers of the transverse conveyor 7 and, sliding along the surface of the guide rods 6, are moved to the exit from the disc-belt flax pulling apparatus. Later, depending on the type of the flax harvesting machine, the stalk tape is either spread on the flax field, or fed to the following working bodies of the flax harvesting machine for combing the seed pods.

The pulling assembly contains fewer parts, so the proposed disk-belt flax pulling apparatus is less material-intensive compared to analogues. Due to the fact that the pulling belts do not transmit traction forces, but only clamp and hold the flax stalks, as well as spring the upper rollers 4, the durability of the pulling belts is ensured.

The geometric dimensions of the pulling section were selected, namely: the width of one pulling section – 0.38 m; radius of the rubberized pulling disk – 0.16 m; diameters of the belt transmission rollers are 0.08 m, thickness of the pulling belt is 10 mm; length of the belt 1 m; width of the pulling disk and pulling belt – 0.1 m; angle of coverage of the pulling disk by the pulling belt - 80º, which in terms of the length of the reach zone is – 0.24 m; angle of inclination of the pulling apparatus to the horizon – 60º and the height of the starting point of harvesting – 0.2 m [6; 7].

The kinematic mode of operation is also theoretically substantiated: the machine speed 2.01 $m \cdot s^{-1}$, circular speed of rotation of the pulling disk or speed of the pulling belt 2.35 $m \cdot s^{-1}$ [6].

The calculated force of the initial tension of the pulling belt was 1 kN. The total power that must be spent on the drive of the pulling section or on the drive of the pulling disk will be 400 W. If there are four pulling sections in the pulling machine, the total drive power of the pulling discs will be 1.6 kW [7].

When the pulling device is installed on a flax puller, the selected stalks are spread out in a ribbon on the field, and when installed on a flax harvester, they are fed to the clamping conveyor to the combing device and placed in the ribbon on the field with a spreading device. The claimed pulling apparatus has four pulling sections and a transverse conveyor. A similar principle of operation, when the construction of the pulling device uses a transverse conveyor, which is designed to take stalks from the pulling sections and transport them to the exit of the pulling device, was used on the LT-4 flax puller or the LK-4A flax harvester. This work is well studied [8] and we believe that its application in our design will be similar.

Therefore, we will determine only the efficiency of the node that changed - the pulling section. The experimental setup consists of only one pulling section, so it only pulls the stems out of the soil. Then the elongated stems fall to the surface of the field, nesting on the already selected stems.

Indicators such as stretched stalks in the tape and skew of the stalks in the tape, which characterize the quality of the flax harvesting machine, were not determined. To check the efficiency of the pulling device, we will consider only two indicators – the purity of pulling flax stalks and the loss of seed pods.

The experimental setup (Fig. 2) was one pulling section with two dividers 1 mounted on a trolley 2. The pulling section consists of a pulling disc 3 and a pulling belt 4 placed on two rollers 5. The pulling disc 3 rotates on bearings mounted on a stationary axis. The drive of the pulling disc 3 was provided with a centering clutch 6, which was fixed in the cartridge of the DeWALT DCH133M1 cordless perforator 7.

The design of the experimental setup allowed changing the following parameters: the speed of movement on the field, frequency of rotation of the pulling disc, tension of the pulling belt, angle of inclination of the pulling section to the horizon, and the pulling height, height of the dividers and the gap between the side bars of the dividers.

The speed of movement of the experimental installation was determined by the distance and time when the installation moved at a constant speed.

The necessary frequency of rotation of the pulling disk was provided by pressing the button of the perforator switch, which worked in the shockless drilling mode. For this purpose, a specially made travel limiter of the switch button was used.


Fig. 2. **Photo of the experimental setup**: 1 – dividers; 2 – cart; 3 – pulling disk; 4 – pulling belt; 5 – rollers; 6 – centering clutch; 7 – cordless perforator

The tension of the pulling belt was adjusted by moving the tension roller in the grooves of the frame of the pulling section. Other adjustments (the angle of inclination of the pulling section to the horizon, and the pulling height, height of the dividers, gap between the side bars of the dividers) were provided by changing the position of the elements of the pulling section on the cart of the experimental setup.

In the experiments, the speed of the experimental setup was approximately constant and equal to 5.4 $km \cdot h^{-1}$ or 1.5 $m \cdot s^{-1}$. This speed was determined by the distance traveled and time. In the experiments, the indicator of the speed mode $\mu$ was changed, which is equal to the ratio of the translational speed $V_m$ of the experimental setup to the circular speed $V_p$ of the pulling disk or the speed of movement of the pulling belt:

$$\mu = \frac{V_m}{V_p}. \quad (1)$$

The required speed $V_p$ was provided by the rotation frequency of the perforator cartridge. To do this, the position of the perforator switch and the rotation frequency were previously calibrated using a frequency meter.

The experimental installation was made to check the performance of the pulling section.

## Results and discussion

The experiments were carried out at the research field of the Department of Agricultural Engineering named after Professor G.A. Khailis of the Lutskyi National Technical University on crops of fibre flax of the Miander variety. According to standard methods [8], the characteristics of sowing were determined: the stem density - 1256 $pcs \cdot m^{-2}$; total height of the stems is 67.4 cm; average diameter of the stem (at 1/3 height) 1.39 mm; area where seed pods are located – 19.2 cm; ripeness phase – yellow; humidity of stems – 50.7%, boxes – 43.0%; weediness – 4.9%; prostrateness - absent.

In the experiments, the circular speed of the pulling disk was varied at three levels - 1.5 $m \cdot s^{-1}$, 2 $m \cdot s^{-1}$ and 3 $m \cdot s^{-1}$. So, as the translational speed was 1.5 $m \cdot s^{-1}$, the indicator of the speed mode $\mu$ was 1, 0.75 and 0.5. The angle of inclination of the plane of the pulling section to the horizon is 60°, the height of the starting point of pulling is 0.2 m.

The purity of pulling and the loss of seed pods were determined. To do this, flax stalks were pulled with an experimental setup (Fig. 3) at the appropriate speed mode. After that, flax stalks pulled out of the ground were carefully pulled up from the area of the field, which corresponds to the width of the harvest (the distance between the nozzles of the dividers) and a length of 2 m. These stalks were lightly shaken on a spread cloth to separate the torn seed pods. After that, these stems were gathered into a bundle. In the same area from which the stalks were taken, all the torn seed pods were pulled up and all the flax stalks that were not pulled out of the soil by the pulling section were pulled out. Seed pods that were pulled up from the surface of the field and those that fell from the stalks onto the canvas were poured into a bag. Also, the stems that were pulled by hand, that is, not pulled by the pulling section, were also tied into a bundle. A tag indicating the test number of the corresponding high-speed mode of operation was attached to these samples.

Fig. 3. **Photo of operation of the experimental installation**

Experiments were carried out in triplicate for each of the levels.

In the laboratory, for each number, seed pods were separated from the flax stalks pulled out of the soil by the pick section and their mass – $m_p$ was determined on electronic scales. The mass of seed pods lost during harvesting was also determined separately – $m_n$. The number of stems pulled out by the harvesting section – $k_p$ and the number of stems that remained unextracted after passing through the experimental setup – $k_n$ were counted. The obtained experimental data were statistically processed [9]. These data were characterized by the coefficient of variation from $\pm 9.6$ % to $\pm 18.9$ % and the accuracy of the experiments from 3.7% to 7.8%. Based on the obtained average arithmetic values, the following indicators were determined.

Losses of seed pods were determined by the formula:

$$\delta = \frac{m_n}{m_p + m_n} 100\% . \quad (2)$$

Purity of pulling was determined by the formula:

$$\alpha = \frac{k_p}{k_p + k_n} 100\% . \quad (3)$$

Diagrams of the influence of the indicator of the speed mode of the pulling section on the purity of pulling and the loss of seed pods were constructed (Fig. 4).

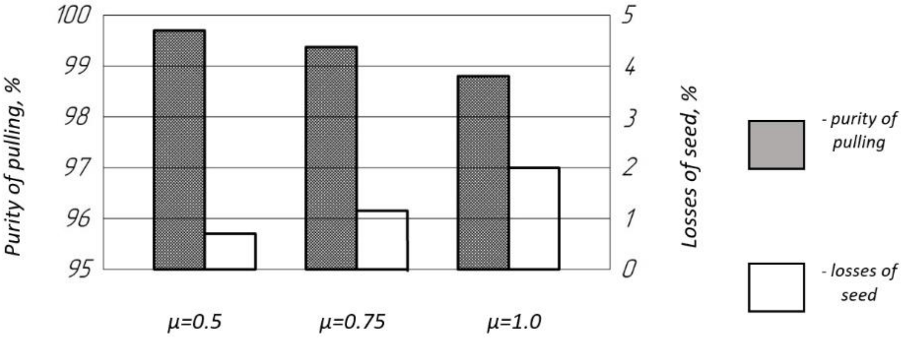


Fig. 4. **Diagram of the influence of the speed mode indicator on the purity of pulling flax stalks and loss of seed**

Analyzing Fig. 4, it can be seen that when the indicator of the speed regime increases from 0.5 to 1, the purity of pulling flax stalks decreases from 99.7% to 98.8%, and the loss of seeds increases from 0.7% to 2.0%. According to the agrotechnical requirements for flax harvesting equipment, the purity of pulling flax stalks is allowed up to 95%, and seed loss - up to 5.0%. That is, the work of the proposed pulling section fully meets the agrotechnical requirements.

The conducted experiments made it possible to check the performance of the pulling section. In order to check the performance of the entire flax-pulling apparatus, it is necessary to manufacture it and check how the selected stalks are taken from each pulling section with the fingers of the transverse conveyor and spreading of the formed stalk tape.

## Conclusions

The influence of the speed mode indicator (the ratio of the forward speed of the installation across the field to the circular speed of rotation of the pulling disk) of the disc-belt pulling apparatus on the purity of pulling and seed loss was determined. The results of the experimental studies confirmed the workability of the proposed design of the disc-belt pulling section. It was established that with an increase in the speed mode indicator from 0.5 to 1, the purity of pulling flax stalks changed from 99.7% to 98.8%, and the loss of seeds – from 0.7% to 2.0%. This gives a reason to assert that the pulling apparatus meets the agrotechnical requirements for flax-harvesting equipment.

## Author contributions

Conceptualization, S.Y.; methodology, S.Y. and Sv.Y.; software, S.Y.; validation, M.T. and N.T.; investigation, S.Y., Sv.Y., M.T. and N.T.; data curation, S.Y. and Sv.Y.; writing – original draft preparation, S.Y.; writing – review and editing, Sv.Y. and N.T.; visualization, S.Y., Sv.Y. and M.T. All authors have read and agreed to the published version of the manuscript.

## References


[1] Zuk M., Richter D., Matuła J., & Szopa J. Linseed, the multipurpose plant. Industrial Crops and Products, 75, Part B, 2015, pp. 165-177. DOI: 10.1016/j.indcrop.2015.05.005

[2] Yang R.B., Li X.J., Tan S.L. Development survey and prospect of flax industry. Modern Agricultural Sciences, 4. 2009. [online][11.02.2024] Available at: http://en.cnki.com.cn/Article_en/CJFDTOTAL-NCSY200904121.htm

[3] Dudarev I. A review of fibre flax harvesting: conditions, technologies, processes and machines. Journal of Natural Fibers, Volume 19, 2022 – Issue 12, pp. 4496-4508. DOI: 10.1080/15440478.2020.1863296

[4] Soucek J., Sturc T., Marecek J. Analysis of linseed production with use of flax puller and combine harvester for its harvest. Acta Univ. Agric. Silvic. Mendelianae Brun, 65, 2017, pp. 511-517.

[5] Дударєв І.М. Теоретичні основи модернізації машин для виробництва льону (Theoretical bases for the modernization of flax production machines). Monograph. Lutsk: Lutsk State Technical University, 2015, 268 p. (In Ukrainian).

[6] Yukhymchuk Sv., Yukhymchuk S., Tolstushko M., Tsiz I., Tolstushko N. Energetics of pulling flax stalks with a disc-belt flax-pulling apparatus. INMATEH – Agricultural Engineering, Romania, Vol. 71, No. 3, 2023, pp. 367-378. DOI: 10.35633/inmateh-71-32

[7] Юхимчук С.М., Юхимчук С.Ф., Толстушко М.М., Дацюк Л.М. Розрахунок бральної секції дисково-пасового льонобрального апарата. (Calculation of pulling section of disc-belt flax-pulling device). Agricultural Machines, Lutsk: LNTY, Vol. 49, 2023, pp. 81-89. (In Ukrainian). DOI: https://doi.org/10.36910/acm.vi49.1023

[8] Хайлис Г. А. Теория и расчет льноуборочных машин (Theory and calculation of flax harvesting machines). Jelgava. Proceedings of Velikoluksky Agricultural Institute. Issue XXVI, 1973, 334 p. (In Russian).

[9] Robert L. Mason, Richard F. Gunst, James L. Hess. Statistical Design and Analysis of Experiments: With Applications to Engineering and Science. 2003. 760 p. DOI:10.1002/0471458503