Improving the performance of flax ribbon tedders

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Abstract. The paper discusses the technology of harvesting fiber flax and the role of flax tedding in this process. Despite its advantages, the existing flax tedders perform the technological process insufficiently, which ultimately leads to a lower yield of long fiber when processing the retted straw at the flax mill. We analyze the performance of flax ribbons tedders and suggest a new construction increasing the intensification and quality of flax tedding.

1. Introduction
In harvesting fiber flax, to maintain the quality of flax raw material during the retting period, turning and tedding of flax ribbons are used, both separately or in combination, alternating each other. The application of flax ribbons turning is limited by a low technological reliability of the used wrappers, while the existing flax strip tedders are reliable and easy to use. However, the application of turning and tedding technologies causes the stalks disorientation in the strip and increases strip stretching. The currently used flax tedders are three-sectional, that is, three flax ribbons are fluffed simultaneously. But the flax ribbons are not always parallel to each other in the field due to the working condition of the pulling machine. In addition, Russian and foreign pullers and flax harvesters form a flax strip with different working widths, while to provide high quality of ribbons after tedding, the fluffing sections of the machines must move strictly along the flax ribbons. This requirement cannot be fulfilled, since the fluffing sections of the machine are fixed relative to the hitch frame in a certain position. The analysis has shown that fluffing drums of the existing tedders do not move strictly along the ribbons but catch only a part of a ribbon, so the tedder teeth do not affect the entire stalk along its length, but only on a part of it, causing the stalks to entangle in the ribbon. It results in a low degree of fluffing (tearing the stalks off the ground). Therefore, the aim of this work is to develop a tedder that can shift sections to move the fluffing drums strictly along the flax ribbons.

2. Materials and methods
The analysis of flax ribbons tedding and tedders work was carried out in the fields of LLC “Utorgosh Flax Mill”. According to the research conditions, the indicators of the initial ribbons had a large scatter: strip width – 60–80 cm; distance between ribbons 30–80 cm; sprouting of ribbons with grass (mass of grass over the strip) – 18-25 g/m²; humidity of stalks – 18–27%, mass of stalks for 1 running meter of the ribbon – 0.50–0.66 kg. Agrotechnical indicators of flax ribbon tedder VL-3 were determined in the aggregate with a tractor MTZ-80.1 using method [9].
3. Research
Flax has long been grown in our country; it serves as a natural raw material for the textile industry. Currently, its production volumes in the Russian Federation have significantly decreased. The main problems in the flax cultivation are the low yield and low quality of the flax retted straw, as well as of the fiber obtained from it [1]. In addition, fiber flax is a laborious and technologically challenging crop. It is possible to provide a sustainable development of flax cultivation having solved two following tasks:

- to improve the flax production quality;
- to reduce significantly the cost of its production by applying resource-saving technologies for cultivating and harvesting fiber flax.

Currently, there are three mechanized technologies for fiber flax harvesting: combine harvester, separate and factory. Combine technology has become widespread in our country due to low labor costs. Its only drawback is that it is impossible to get good seeds and fiber at the same time because of different ripening times. Separate technology has not found wide application because of its great dependence on weather conditions. However, it is promising, as the combing of seed bolls passes through 5–7 days after flax stalks pulling. Factory harvesting technology used in a number of European countries has large seed losses and therefore has not yet been applied in our country.

In most farms, retted straw is obtained by field retting. It takes about three weeks under favorable conditions, but due to prolonged bad weather this period increases by a month or more. With the prolonged retting, the flax ribbons are beaten to the soil by the rains and sprouted with grass. In such ribbons, retting occurs unevenly in their thickness, and in case of prolonged rainy weather, the lower stalks of flax rot and the upper stalks are overretted, which leads to a decrease in the retted straw quality.

Depending on the weather conditions and flax yield, the ribbons are turned during retting [2]. It accelerates the retting and obtaining of fiber homogeneous in separability and color, reduces the possibility of decay of the lower layer. This operation improves the retted straw quality by 0.25–0.5 points.

Most flax-growing farms do not perform the stalk turning operation, due to the low technological reliability of the flax ribbon turners used and their low performance. In addition, due to a lack of financial resources, farm managers consider this operation “optional”.

A complex approach of turning alternated with tedding gives a positive effect. It prevents spoiling of retted straw and increases its uniformity in moisture and color. However, the application of these operations increases stretching of stalks in the ribbon, which leads to a decrease in the yield of long fiber when processing straw at the flax mill.

Tedding of flax ribbons is less effective compared to turning of stalks (especially when the yield of the retted straw is 3.0 t/ha and above), since it does not ensure the uniformity of the flax straw. However, it is a necessary operation on flax harvesting. Tedding is applied if the stalks are beaten to the ground by rains and sprouted by weeds, when air exchange sharply decreases in them [5]. Tedding is also used before picking the retted straw by balers, which allows to increase their productivity and cleanliness of flax raw material in the roll.

At the Utorgosh Flax Mill in the Novgorod Region, flax ribbons are not turned, but tedding is widely used. In addition, due to the lack of financial resources, the treatment of fields with herbicides is carried out selectively. Therefore, flax ribbons are quickly sprouted with weeds during the retting period. Tedding of flax ribbons ensures combing of the stalks from the grass, so the fluffed stalks are located on the grass cover, which prevents roetting of their lower layer in the ribbons.

Currently, to maintain the quality of flax raw materials during the retting period, tedders of flax ribbons VL-3, VLN-3, VLN-4,5, VLK-3M and others are widely used. They are simple in design, have high technological reliability and performance. When tedding, the stalk mass is separated from the ground, combed out from the sprouted grass, on which it was dumped in a fluffed state. This creates a favorable air regime both on top of the ribbon and from below, which eliminates the decay of the lower layer of stalks.
However, tedders of flax ribbons mix up the stalk mass and increase the uneven spread of ribbons, the angle of deviation of the stalks in the ribbon, the stalk stretching in the fluffed ribbon; and the shortage of stalks reaches 10% (not all stalks come off the ground and are combed out from the grass).

When processing a layer having excessive extension and entanglement of the stalks, the yield of long fiber from the retted straw decreases, which reduces the flax mill efficiency. The yield of long fiber during the processing of retted straw rarely exceeds 9–10% of its mass (when the fiber content in the stalks is up to 32%) [4].

At present, high-performance three-sectional tedders are used. The first flax tedders were two-sectional, and the tractor moved its wheels along the flax ribbons, which caused additional damage to the stalks [6].

The tedding process is also influenced by the design and kinematic parameters of the machine. The greatest impact on the stalk mass has an indicator of the kinematic mode \( \lambda = \frac{V_t}{V_m} \), where \( V_t \) – the tooth linear speed, \( V_m \) – the machine translational speed. The tedder teeth trajectory is a shortened cycloid \( \lambda < 1 \). Based on the theoretical and experimental studies, the kinematic regime indicator \( \lambda = 0,8–0,9 \) [7]. Under the most difficult working conditions, when flax ribbons are beaten to the soil by rains and the density of grass stands exceeds 0,2 kg/m\(^2\), it matters the least. In this mode, the tedders teeth trajectories, working sequentially one after another, intersect at the exit of the flax ribbon. As a result, all the flax stalks come off the soil and their losses are minimal.

However, on the other hand, it increases the unevenness of the flax ribbon spread, which affects the uniformity of retting. Under normal operating conditions, the kinematic mode indicator should have a maximum value at the machine speed of 10–12 km/h.

In addition, in order not to confuse the stalk mass and to ensure that all stalks are separated from the soil, the fluffing drums of the tedders must capture the entire ribbon in width, that is, the middle of the drums should move in the middle of the ribbon. However, flax ribbons are often located at different distances from each other. Two ribbons can contact the stems or diverge from each other at a distance of one meter. This is due to the working conditions of the flax harvester: productivity, field topography unevenness, stalk height, beating down of stalks, weediness and other.

Another feature of flax tedders operation is that the pulling machines (flax pullers, Russian and foreign flax harvesters) have different working widths. Russian pullers: TLN-1,5А, TPK-4К; flax harvesters LK-4А, KLP-1,5, «Rusich» have working width of 1,52 m and form the ribbon of this width. Foreign pullers of Union, Deporte (Belgium), Dehondt (France) etc., including those issued in joint enterprises in Belorussia, for the ribbon of 1,2 m.

Flax tedders, which are currently produced, are adapted only to the specific working width of the pulling machines. The fluffing drums sections are fixed in one position relative to the hitch frame. Therefore, during operation, the fluffing drums capture part of the flax ribbon, which leads to poor-quality execution of the process.

To solve the problems mentioned above, we suggest an improved flax tedder construction [8]; its scheme is shown on figure 1.
Figure 1. Flax tedder.

The general frame of the tedder is made integral and includes three parts: a central 11 with an automatic coupler 1 and two laterals 12 and 13. These parts are made of square or rectangular sections. The laterals are located in the central part and move in it by hydraulic cylinders 14, which are fixed in the eyes of these parts.

Fluffing drums of the tedder are driven by support wheels 4 through a retarding chain gear 8. Movement of teeth 7 occurs on a shortened cycloid, and consists of the unit speed and the peripheral speed of the teeth ends. When the machine is operating, they alternately enter the flax ribbon, pick up and tear the flax stalks from the ground and raise them to the removable grid 3, with the help of which they are dumped on the soil in a fluffy state.

When changing the distance between the flax ribbons, the machine operator shifts the extreme sections 2 left or right using the hydraulic cylinders 14, thereby reducing or increasing the distance between the central and side sections, directing the fluffing drums precisely along the ribbons.

Thus, the flax tedder can simultaneously flush three flax ribbons with a width of 1.20 to 1.52 m in one pass and can be used regardless of the pulling machine working width and their working condition in the field.

4. Conclusion
The use of flax tedder with the possibility of hydraulic adjustment of the tedder sections position will allow the fluffing drums to move precisely along the ribbons. The tedder teeth thus affect the entire flax
stalk along its length without changing its position relative to other stalks in the ribbon. Consequently, the stalks position in the ribbon after tedding does not practically change compared to the initial one; the stalks stretching in the tape, their deviation angle, the ribbon spread unevenness can increase only insignificantly (their values will not exceed the specifications for technical conditions), and the fluffing fullness will reach 100 %. The use of the considered tedder will improve the quality of retting obtained in the field, and, consequently, increase the quality and yield of long fibers. The cost of the suggested tedder will not increase in comparison with the current tedders. The changes will affect only the hitch frame, and two hydraulic cylinders with high pressure hoses will be added. But considering that the fluffing drums of this tedder can move strictly along the flax ribbons, the number of discs with teeth in each section will be reduced to six pieces. This will not only reduce the weight of the tedder, but also its cost.

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