UDC 621.3
DOI: 10.37128/2520-6168-2024-4-7

TRENDS IN THE APPLICATION OF NEW TECHNOLOGIES AND MACHINES FOR HARVESTING BIOENERGY CROPS

Olena TRUKHANSKA, Candidate of Technical Sciences, Associate Professor
Bohdan PERKHAILO, Recipient of the First Educational and Qualification Level
Vinnytsia National Agrarian University

ТРУХАНСЬКА Олена Олександрівна, к.т.н., доцент
ПЕРХАЙЛО Богдан Павлович, здобувач першого освітньо-кваліфікаційного рівня
Вінницький національний аграрний університет

An analysis of the design features and technological processes of the functioning of working bodies intended for One of the main areas of use of renewable energy sources in Ukraine is biomass energy. The bioenergy industry in Ukraine has the greatest development potential. This is due to the peculiarities of the climate, the potential of the agricultural sector and the availability of the necessary labor force. The greatest energy potential in Ukraine is possessed by such types of biomass as agricultural crops. Among the promising crops for green energy, both in the world and in Ukraine, energy willow is distinguished. Willow plantations are established in an area of sufficient moisture with a high level of groundwater.

The article is devoted to the problem of harvesting and saving means of drying crushed willow mass for further use. In today's conditions, the problem of energy resources arises in the winter period. The production of solid types of biofuels - granules and briquettes - has gained the greatest development in Ukraine. The main raw materials for the production of solid biofuels are woodworking industry waste (sawdust, chips), straw of grain and leguminous crops, sunflower husks, etc. The production of such raw materials is unstable and seasonal, which negatively affects the efficiency of solid biofuel production plants.

Energy willow is the main energy bioculture grown in agriculture. Willow is a fast-growing tree, the crushed mass of which is used to produce energy, and it is also an environmentally friendly raw material for the production of fuel pellets and briquettes suitable for burning in boilers.

Based on comprehensive scientific research, taking into account biological, agrotechnical, technological and economic features, elements of the technology for growing energy willow in different agroclimatic zones of Ukraine have been developed. As a result, a technology for growing energy willow has been developed for the first time, which ensures a yield of biological raw materials of 40-70 t/ha and its use.

Given the high importance of using energy willow as a solid biofuel, its harvesting and processing are of great importance in the technology.

Key words: *biofuel, energy willow, technology, harvesting, processing, flattening, aggregate, efficiency.*
Eq. 11. Fig. 4. Ref. 13.

1. Problem formulation

One of the important factors in growing energy willow plantations is appropriate support for producers from the state. The concept of sustainable development, developed by European countries, provides for the rational use of natural resources. This issue has become particularly relevant for both Ukraine and other countries that are faced with the problems of providing industry and the population with energy resources, which involves the energy security of the state, in particular, reducing dependence on gas supplies. The reason for this state of affairs is the depletion of natural resources, in particular gas, oil, coal [1].

To solve this problem, bioenergy is being actively introduced and developed, which, in addition to the energy received, leads to a reduction in the negative impact on the environment. Currently, special combines are used for cutting and processing wood mass on energy plantations [2].

The flow method of harvesting energy crops is the most common with large-scale harvesting of energy crop biomass. This method allows you to reduce the costs of planning, management, etc. per unit of production - fuel chips. Currently, great attention when harvesting energy crops is paid to flattening the stem for subsequent drying and grinding [3].

2. Analysis of recent research and publications

A number of studies and publications are devoted to the analysis of technological processes of flattening, as well as the designs of machines for harvesting and harvesting bioenergy crops [3, 5-9].

In the work [3] it is noted that when drying crops in natural conditions, uneven drying of individual parts of plants is observed. Leaves dry 2–3 times faster than stems, which is especially negative when harvesting energy crops. For example, with stem humidity within 40–45%, leaves have a humidity of about 16%. Rough and juicy stems dry slowly, and the leaf part dries out and easily falls off with further mechanical action, which leads to an unacceptable increase in crop losses, including its most valuable part - leaves. To ensure uniform drying of all parts of plants, the drying rate of stems should be approximately equal to the rate of moisture loss by leaves. This can be achieved by flattening the plant mass.

In works [5-7], the designs of mowers with different types of cutting devices were considered and their efficiency was assessed in terms of agrotechnical, operational-technological, energy and economic indicators.

The flattening rollers can be with a metal or polyurethane surface and have a different surface shape - smooth or ribbed. For example, the KUHN flattening system consists of two polyurethane rollers with a QUADROFLEX profile, which is formed by successively placed protrusions and depressions on the surface of the rollers, which form ribs in the form of a broken line [8].

When the rollers rotate, the protrusions on one of them enter the depressions on the other, and the ribs of the roller surfaces converge from the edges to the center, performing flattening of plants in both the longitudinal and transverse directions. In this case, in addition to the gentle flattening of plant stems, the natural wax coating is removed (macerated) from their surface, which also accelerates moisture release [8].

In the work [9] it is noted that for flattening plant mass, a drum-type working body is also used - a drum with flails with a rotation frequency of 600 - 1000 rpm. The flails are made of steel or synthetic materials, with a round or rectangular cross-section, 150 - 200 mm long, of various configurations: V-shaped, finger, hammer, which can be attached to the drum rigidly or hingedly. Flattening of the beveled plant mass, together with the removal of the natural wax coating from their surface, occurs due to impact, pulling it along the inner surface of the casing of the flattening device or pulling it between the fingers placed in the working area of the flails.

3. The purpose of the article

The purpose of the research is The purpose of the research is to improve the efficiency of the unit for flattening raw materials by intensifying the process of harvesting bioenergy crops.

4. Results of the researches

The task of mechanical processing of reeds for fiber is to destroy the wood of the stem and separate it from the fiber. This process includes the processes of flattening. Flattening of the plant mass is carried out simultaneously with mowing grass in favorable weather for drying biomass. The flattening rollers of the mower-flatter should not grind the plant mass. Grinding of the plant mass by flattening rollers leads to losses of leaf and stem parts. The completeness of flattening of the material should be at least 90% [4, 10].

Flattening is the process of passing the plant mass between two parallel, horizontally placed one above the other cylindrical rollers with counter-rotation, which compress the plant mass with a certain force, destroying the covering tissue of the stems (skin) with the formation of transverse breaks and longitudinal cracks on it, through which the stems quickly lose moisture.

The increase in the difference in stiffness between fiber and wood is achieved by pre-drying the reed from a moisture content of 12 - 13% to a moisture content of 6 - 8%. When the moisture content changes in this range, the flexibility and strength of the fiber decrease slightly, and the stiffness of the reed increases sharply, which increases the effectiveness of the crushing effects [11, 12].

With the transshipment method of harvesting energy willow, the biomass collected by combines is unloaded on the go into a transport trailer and taken to the edge of the field, where it is placed in field piles for temporary storage (Fig. 1).

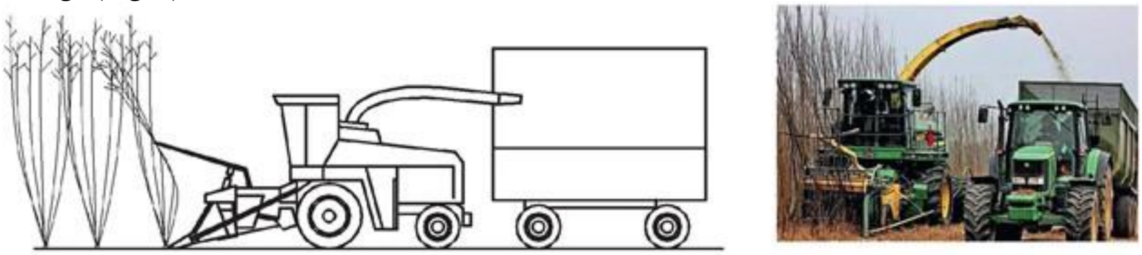

Fig. 1. Harvesting energy willow with a self-propelled harvester.

Currently, there are several schemes of compactors (Fig. 2), which to one degree or another correspond to the specific features of the machine designs.

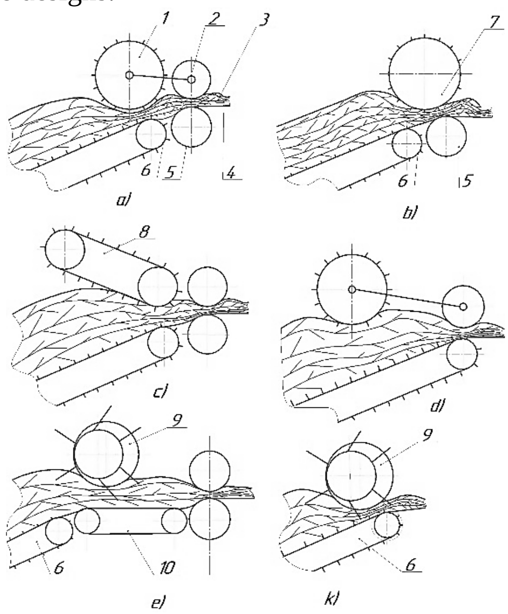

Fig. 2. Schemes of flattening devices with different narrowing coefficients of plant raw materials:
1 – receiving beater; 2 – upper flattening roller; 3 – plant biomaterial; 4 – conveyor plate; 5 – lower flattening roller; 6 – conveyor; 7 – upper flattening roller; 8 – upper feeding conveyor; 9 – feeding roller with retractable fingers; 10 – lower feeding conveyor.

The most important parameter for the process of compacting rollers - the angle α of the mass layer capture (Fig. 3) can be determined depending on the diameter D of the rollers, the thickness H of the mass layer entering the rollers, and the thickness of the mass layer compacted by the rollers [11, 13].

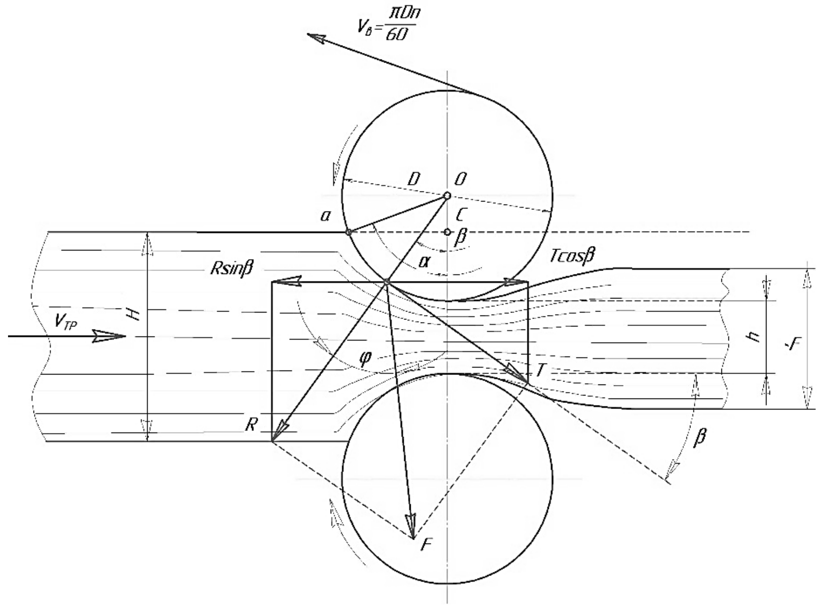

Fig. 3. Scheme for calculating the diameter of the flattening rollers.

The thickness of the layer of mass entering the rollers is calculated:

$$\frac{H-h}{2}=\frac{B}{2}-\frac{D}{2}cos\,\alpha\,. \quad (1)$$

$$H-h=D\cdot(1-cos\,\alpha\,)\,. \quad (2)$$

The diameter of the rollers is calculated using the formula:

$$D = \frac{H - h}{1 - cos\,\beta}, \tag{3}$$

where β – the wedge angle.

Considering the interaction of the roller with the layer of incoming mass (Fig. 3), it is seen that it comes from the side of the rollers, taking into account the reaction R and the friction force T. Their resultant force F can be directed towards the rollers when φ > β; vertically when φ = β; away from the rollers when φ < β. The rollers capture and pull the mass when φ > β, when φ = β the mass slips and when φ < β it is repelled. The point of application and the magnitude of the resultant force F are not constant, they change in the process of mass advancement depending on the ratio of forces. In steady motion, the force F is applied closer to the middle of the contact arc ab. Since the angle φ between the reaction R and the resultant F is equal to the angle of friction, then in a steady process of mass movement in the rollers always φ > β.

The friction force is calculated:

$$T = Rf, \tag{4}$$

where the friction coefficient $f = tg\ \varphi$, respectively:

$$Rf \cdot cos\,\beta > R \cdot sin\,\beta, \tag{5}$$

$$f > tg\beta,\ tg\varphi > tg\beta,\ \ \varphi > \beta. \tag{6}$$

Let's calculate the diameter of the rollers D:

$$D = \frac{H - h}{1 - \frac{1}{\sqrt{1 + tg^2\beta}}}. \tag{7}$$

The upper roller is made with special ridges, with a diameter of 150 - 300 mm, which increases their adhesion to the captured mass several times.

The speed of the flattening roller υ_v should ensure unhindered tightening of the captured mass with a speed υ_{tr}.

The required speed of the flattening rollers, which ensures unhindered flow of the mass of a given thickness *H*, can be obtained from the expression:

$$\upsilon_в = \frac{D\upsilon_{тр}}{D + h - H}. \tag{8}$$

$$\frac{\upsilon_в}{\upsilon_{тр}} = \frac{D}{D + h - H}. \tag{9}$$

The permissible thickness of the feed mass layer is calculated:

$$H = h + D \cdot \left(1 - \frac{\upsilon_{nh}}{\upsilon_d}\right). \tag{10}$$

To ensure reliable transfer of mass to the lower compacting roller and prevent mass from being drawn into the gap between the conveyor and the roller, the following is adopted:

$$\frac{\upsilon_в}{\upsilon_{тр}} = 1{,}25...1{,}35. \tag{11}$$

To select a scheme for a machine for harvesting energy crops by flattening, we select a trailed machine with disk cutting working bodies, a roller flattening device, a conveyor for feeding the collected material into the vehicle. The composition and operation of the unit for harvesting energy crops by flattening are shown in (Fig. 4).

Machine for harvesting energy crops by flattening (Fig. 4). consists of an energy carrier 1 (tractor), a header 4 with rotary working cutting elements 9, the header is attached to the energy carrier by a hitch 2, the header is equipped with receiving rollers 5 to direct the mass to the conditioner, and conditioner rollers 6 to flatten the crop, an inclined conveyor 7 is installed to transport the flattened mass to the trailer 8, which feeds the mass into the vehicle, a tractor trailer 8 is attached to the header frame, which transports the flattened mass to the place of drying and processing.

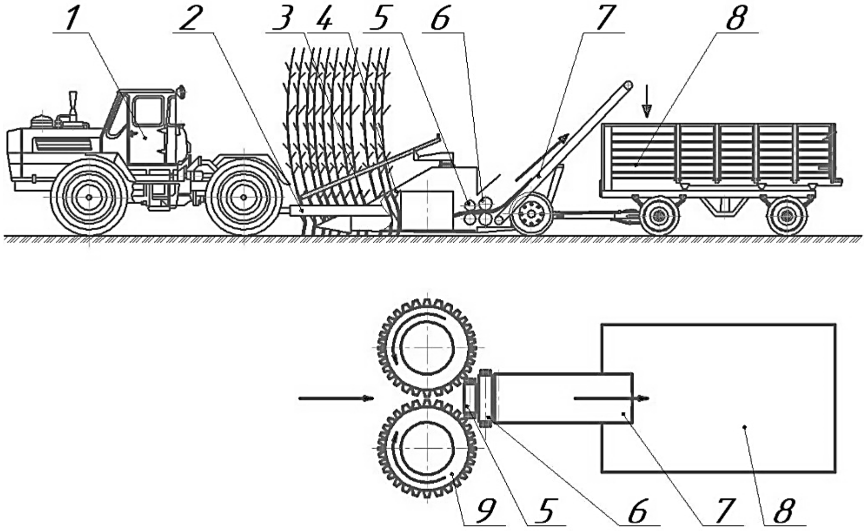

Fig. 4. Scheme of a trailed unit for harvesting energy crops by flattening:
1 – tractor; 2 – header trailed device; 3 – energy crop; 4 – header; 5 – receiving rollers; 6 – flattening device; 7 – conveyor; 8 – trailer; 9 – cutting device.

5. Conclusions

The use of mechanized technologies in harvesting bioenergy crops is currently relevant when using renewable energy sources.

A scheme of a flattening device using two types of feed rollers is proposed. The interaction of feed and flattening rollers with a corrugated coating will increase the efficiency of the unit and the quality of flattening of the cut material, which will lead to a reduction in costs by eliminating the forced drying operation.

References

1. Kaletnik, H.M. (2013). Rozvytok rynku biopalyv v Ukraini. *Bioenerhetyka, 1,* 11–16. [in Ukrainian].
2. Kaletnik, H.M. (2010). *Biopalyva: efektyvnist yikh vyrobnytstva ta spozhyvannia v APK Ukrainy: navch. posibnyk.* K: Ahrarna nauka. [in Ukrainian].
3. Humentyk, M.Ya., Radeiko, B.M., Fuchylo, Ya.D. (2018). *Vyroshchuvannia bioenerhetychnykh kultur: monohrafiia.* K.: TOV «TsP «Komprynt». [in Ukrainian].
4. Kondratiuk, D.H., Hryhoryshen, V.M., Trukhanska, O.O. (2009). Klasyfikatsiia mashyn dlia vorushinnia, zghribannia i perevertannia trav. *Visnyk Dnipropetrovskoho derzhavnoho ahrarnoho universytetu. 2,* 109–112. [in Ukrainian].
5. Kosarka-pliushchylka KUHN FC 3161 TCR. URL: https://www.titanmachinery.ua/silskogospodarski-mashini/kosarki-1/kosarka-plyushchilka-fc-3161-tcr.html. (data zvernennia 10.10.2024 r.) [in Ukrainian].
6. Kondratiuk, D.H., Trukhanska, O.O., Priadkin, M.O. (2024). Analiz konstruktsii rotatsiinykh kosarok – pliushchylok. *Tekhnika, enerhetyka, transport APK, 1 (124),* 106–114. [in Ukrainian].
7. Shkoropad, L. (2017). Kompleksy mashyn dlia tekhnolohii sinozahotivli. *Tekhnika i tekhnolohii APK. 7 (94),* 7–11. [in Ukrainian].
8. Smolinskyi, S., Smolinska, A., Marchenko, V. (2017). Kosarky dlia zahotivli yakisnykh kormiv. *Agroexpert, 5,* 58–62. [in Ukrainian].
9. Malakov, O.I. (2018). Suchasnyi stan tekhnichnoho rivnia mashyn dlia skoshuvannia trav na sino. *Tekhnika, enerhetyka, transport APK, 2 (101),* 139–144. [in Ukrainian].
10. Zhukov, V.P., Panko, V.V., Trukhanska, O.O. (2013). Otsinka tekhnolohichnykh pryiomiv sukhoho fraktsiiuvannia sina pryrodnoho sushinnia dlia otrymannia hranul. *Zbirnyk naukovykh prats Vinnytskoho*

natsionalnoho ahrarnoho universytetu. Seriia: Silskohospodarski nauky, 2 (72), 1, 12–18. [in Ukrainian].
11. Voitiuk, D.H., Baranovskkyi, V.M., Bulhakov, V.M. (2005). *Silskohospodarski mashyny. Osnovy teorii ta rozrakhunku: Pidruchnyk*. K.: Vyshcha osvita. [in Ukrainian].
12. Kharakterystyka tekhnolohichnykh protsesiv pliushchennia. Ahrotekhnichni vymohy. URL: https://tandf.in.ua/animal-feed-conditioning (data zvernennia 10.10.2024 r.). [in Ukrainian].
13. Komakha, V.P. (2012). Udoskonalennia tekhnolohichnoho protsesu ta obgruntuvannia parametriv kosarky-pliushchylky : dys. kand. tekhn. nauk : 05.05.11. Vinnytskyi nats. ahrarnyi un-t. Vinnytsia, 173p. [in Ukrainian].

ТЕНДЕНЦІЇ ЗАСТОСУВАННЯ НОВИХ ТЕХНОЛОГІЙ І МАШИН ДЛЯ ЗБИРАННЯ БІОНЕРГЕТИЧНИХ КУЛЬТУР

Стаття присвячена проблемі збирання врожаю та економії засобів сушіння подрібненої маси верби для подальшого використання.

В умовах сьогодення виникає проблема енергетичних ресурсів у зимовий період. Найбільшого розвитку в Україні набуло виробництво твердих видів біопалива гранул і брикетів. Переважно сировиною для виробництва твердого біопалива є відходи деревообробної промисловості (тирса, тріска), солома зернових і зернобобових культур, соняшникова лузга тощо. Виробництво такої сировини є нестабільним і має сезонний характер, що негативно впливає на ефективність роботи заводів із виробництва твердого біопалива.

Енергетична верба являється основною енергетичною біокультурою, яка вирощується в сільському господарстві. Верба це швидкоросле дерево, подрібнена маса якої використовуються для виробництва енергії, а також це екологічно чиста сировина для виробництва паливних гранул та брикетів, придатних до спалювання в котлах.

На основі комплексних наукових досліджень з урахуванням біологічних, агротехнічних, технологічних та економічних особливостей розроблені елементи технології вирощування енергетичної верби в умовах різних агрокліматичних зон України. В результаті вперше розроблена технологія вирощування енергетичної верби, яка забезпечує урожайність біологічної сировини 40-70 т/га та її використання.

Враховуючи високе значення використання енергетичної верби, як твердого біопалива велике значення в технології займає її збирання та переробка.

Ключові слова: *біопаливо, енергетична верба, технологія, збирання, переробка, плющення, агрегат, ефективність.*

Ф. 11. Рис. 4. Літ. 13.

INFORMATION ABOUT THE AUTHORS

Olena TRUKHANSKA – Candidate of Technical Sciences, Associate Professor, Associate Professor of the Department of Agroengineering and Technical Service of Vinnytsia National Agrarian University (Soniachna Str., 3, Vinnytsia, 21008, Ukraine, e-mail: seaswallow@ukr.net, https://orcid.org/0000-0001-8481-8878).
Bohdan PERKHAILO – Recipient of the First Educational and Qualification Level of Vinnytsia National Agrarian University (Soniachna Str., 3, Vinnytsia, 21008, Ukraine, e-mail: seaswallow@ukr.net).

ТРУХАНСЬКА Олена Олександрівна – кандидат технічних наук, доцент, доцент кафедри агроінженерії та технічного сервісу Вінницького національного аграрного університету (ВНАУ, вул. Сонячна, 3, м. Вінниця, Україна, 21008, e-mail: seaswallow@ukr.net, https://orcid.org/0000-0001-8481-8878).
ПЕРХАЙЛО Богдан Павлович – здобувач першого освітньо-кваліфікаційного рівня Вінницького національного аграрного університету (ВНАУ, вул. Сонячна, 3, м. Вінниця, Україна, 21008, e-mail: seaswallow@ukr.net).