



Всеукраїнський науково-технічний журнал

All-Ukrainian Scientific & Technical Journal

ISSN 2520-6168 (Print)

DOI:10.37128/2520-6168-2021-2

**Machinery
Energetics
Transport
of Agribusiness**



**ТЕХНІКА
ЕНЕРГЕТИКА
ТРАНСПОРТ АПК**



Всеукраїнський науково-технічний журнал

**ТЕХНІКА,
ЕНЕРГЕТИКА,
ТРАНСПОРТ АПК**

№ 2 (113) / 2021

м. Вінниця - 2021

**ТЕХНІКА,
ЕНЕРГЕТИКА,
ТРАНСПОРТ АПК**

Журнал науково-виробничого та навчального спрямування
Видавець: Вінницький національний аграрний університет

Заснований у 1997 році під назвою «Вісник Вінницького державного сільськогосподарського інституту».
Правонаступник видання: Збірник наукових праць Вінницького національного аграрного університету. Серія: Технічні науки.
Свідоцтво про державну реєстрацію засобів масової інформації
КВ № 16644–5116 ПР від 30.04.2010 р.

Всеукраїнський науково – технічний журнал «Техніка, енергетика, транспорт АПК» / Редколегія: Токарчук О.А. (головний редактор) та інші. Вінниця, 2021. 2(113). С. 177.

Друкується за рішенням Вченої ради Вінницького національного аграрного університету (протокол № 12 від 29.06.2021 р.)

Свідоцтво про державну реєстрацію засобів масової інформації №21906-11806 Р від 12.03.2016р.

Журнал «Техніка, енергетика, транспорт АПК» включено до переліку наукових фахових видань України з технічних наук (Категорія «Б», Наказ Міністерства освіти і науки України від 02.07.2020 року №886);

- присвоєно ідентифікатор цифрового об'єкта (Digital Object Identifier – DOI);

- індексується в CrossRef, Google Scholar;

- індексується в міжнародній наукометричній базі [Index Copernicus Value](#) з 2018 року.

Головний редактор

Токарчук О.А. – к.т.н., доц., Вінницький національний аграрний університет

Заступник головного редактора

Веселовська Н.Р. – д.т.н., проф., Вінницький національний аграрний університет

Відповідальний секретар

Полєвода Ю.А. – к.т.н., доц., Вінницький національний аграрний університет

Члени редакційної колегії

Булгаков В.М. – д.т.н., проф., академік НААН, Національний університет біоресурсів і природокористування України

Севостьянов І.В. – д.т.н., проф., Вінницький національний аграрний університет

Граняк В.Ф. – к.т.н., доц., Вінницький національний технічний університет

Спірін А.В. – к.т.н., доц., Вінницький національний аграрний університет

Іванчук Я.В. – к.т.н., доц., Вінницький національний технічний університет

Твердохліб І.В. – д.т.н., доц., Вінницький національний аграрний університет

Іскович – Лотоцький Р.Д. – д.т.н., проф., Вінницький національний технічний університет

Цуркан О.В. – д.т.н., доц., Вінницький національний аграрний університет

Купчук І.М. – к.т.н., доц., Вінницький національний аграрний університет

Яронуд В.М. – к.т.н., доц., Вінницький національний аграрний університет

Зарубіжні члени редакційної колегії

Йордан Максимов – д.т.н., професор Технічного університету Габрово (Болгарія)

Відповідальний секретар редакції **Полєвода Ю.А.** кандидат технічних наук, доцент
Адреса редакції: 21008, Вінниця, вул. Сонячна 3, Вінницький національний аграрний університет, тел. (0432) 46–00–03

Сайт журналу: <http://tetapk.vsau.org/>

Електронна адреса: pophv@ukr.net

**I. ПРИКЛАДНА МЕХАНІКА. МАТЕРІАЛОЗНАВСТВО. ГАЛУЗЕВЕ МАШИНОБУДУВАННЯ.***Веселовська Н.Р., Гайдамак О.Л., Карпійчук М.Ф., Кучеренко Ю.С.***ПРОЦЕСИ ТА ТЕХНОЛОГІЇ ХОЛОДНОГО ГАЗОДИНАМІЧНОГО НАПИЛЕННЯ
ВИРОБІВ СІЛЬСЬКОГОСПОДАРСЬКОЇ ТЕХНІКИ..... 4***Ivan Sevostianov, Oleksii Tokarchuk, Maryna Pidlypna***AUTOMATED TECHNOLOGICAL PROJECTION OF CLASSIFICATION PROCESSES OF
DRY DISPERSIVE MATERIALS..... 15***Михалевич В.М., Матвійчук В.А., Бубновська І.А.***ОЦІНКА ДЕФОРМОВНОСТІ МАТЕРІАЛУ ЗАГОТОВОК ПРИ ВАЛЬЦЮВАННІ..... 22***Островський А.Й.***УДОСКОНАЛЕННЯ ПРОЦЕСУ ВІДБОРТУВАННЯ КРУГЛОГО ОТВОРУ У
ЛИСТОВИХ ЗАГОТОВКАХ..... 31***Serhiy Shargorodskiy, Volodymyr Rutkevych***INFLUENCE OF PHYSICAL AND MECHANICAL PROPERTIES OF STEM FEED AND
DESIGN OF THE WORKING BODY ON THE DRIVE POWER OF THE CUTTING
MECHANISM..... 38***Yurii Polievoda, Alla Solomon***THE CHOICE OF FACTORS OF INFLUENCE ON VIBRO-CENTRIC SEPARATION OF
LIQUID INHOMOGENEOUS RAW MATERSALS 50****II. ЕЛЕКТРОЕНЕРГЕТИКА, ЕЛЕКТРОТЕХНІКА ТА ЕЛЕКТРОМЕХАНІКА***Возняк О.М., Штуць А.А., Замрій М.А.***СИСТЕМА УПРАВЛІННЯ КОЛЕКТОРНИМ ДВИГУНОМ..... 57****III. АГРОІНЖЕНЕРІЯ***Анісімов В.Ф., Сленич А.П.***ОСОБЛИВОСТІ КОНСТРУКЦІЇ ПАЛИВНОЇ АПАРАТУРИ ТА ЗБІЛЬШЕННЯ
ТЕРМІНУ ЇЇ ЕКСПЛУАТАЦІЇ..... 67***Бабин І.А.***РЕЗУЛЬТАТИ ВИРОБНИЧОЇ ПЕРЕВІРКИ АВТОМАТИЧНОЇ СИСТЕМИ
ПРОМИВАННЯ МОЛОКОПРОВІДНОЇ ЛІНІЇ ДОЇЛЬНИХ УСТАНОВОК..... 78***Гулько І.В.***ТЕНДЕНЦІЇ ДИВЕРСИФІКАЦІЇ ЕНЕРГОНОСІВ МАШИНИХ АГРЕГАТИВ..... 88***Гулько І.В., Левчук О.В.***ТЕХНОЛОГІЯ ЗМІШАНОГО НАВЧАННЯ МАЙБУТНІХ ІНЖЕНЕРІВ-МЕХАНІКІВ В
УМОВАХ ННВК «ВСЕУКРАЇНСЬКИЙ НАУКОВО-НАВЧАЛЬНИЙ КОНСОРЦІУМ»..... 97***Котов Б.І., Калініченко Р.А., Рудь А.В., Грушецький С.М.***ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ ОХОЛОДЖЕННЯ ЗЕРНА ПІСЛЯ СУШІННЯ І
ТЕРМООБРОБКИ..... 111***Пришляк В.М., Дубчак В.М.***ТЕОРІЯ І ПРАКТИКА РУХУ СІЛЬСЬКОГОСПОДАРСЬКИХ МАТЕРІАЛІВ У
РІДИННОМУ ТА ПОВІТРЯНОМУ СЕРЕДОВИЩАХ ЗА УМОВИ ДІЇ
ГРАВІТАЦІЙНОГО ПОЛЯ..... 121***Пришляк В.М., Мизюк А.І.***СИСТЕМНИЙ АНАЛІЗ АГРОТЕХНІЧНИХ І МЕХАНІКО-ТЕХНОЛОГІЧНИХ
ПЕРЕДУМОВ ДО РОЗРАХУНКУ, ПРОЕКТУВАННЯ ТА КОНСТРУЮВАННЯ
КАРТОПЛЕСАДЖАЛОК***Спірін А.В., Твердохліб І.В., Купчук І.М., Побережець Ю.М.***ОБҐРУНТУВАННЯ ЕНЕРГОЕФЕКТИВНИХ РЕЖИМІВ ПРОЦЕСУ ДОСУШУВАННЯ
ПРОДУКТІВ ФРАКЦІЙНОЇ ПЕРЕРОБКИ ЛЮЦЕРНИ..... 142***Холодюк О.В.***ПРАКТИЧНІ АСПЕКТИ ВИКОРИСТАННЯ БЕЗПЛОТНОГО ЛІТАЛЬНОГО АПАРАТУ
AGRAS T16..... 152***Яропуд В. М., Алієв Е.Б.***РЕЗУЛЬТАТИ ОБСТЕЖЕННЯ СТАНУ ЗАБЕЗПЕЧЕННЯ МІКРОКЛІМАТУ В
СВИНАРНИКУ ІЗ СИСТЕМОЮ ВЕНТИЛЯЦІЇ ВІД'ЄМНОГО ТИСКУ..... 168**



UDC 631.363:636.22/28

DOI: 10.37128/2520-6168-2021-2-5

INFLUENCE OF PHYSICAL AND MECHANICAL PROPERTIES OF STEM FEED AND DESIGN OF THE WORKING BODY ON THE DRIVE POWER OF THE CUTTING MECHANISM

Serhiy Shargorodskiy, Ph.D., Associate Professor
Volodymyr Rutkevych, Ph.D., Associate Professor
Vinnitsia National Agrarian University

Шаргородський Сергій Анатолійович, к.т.н., доцент
Руткевич Володимир Степанович, к.т.н., доцент
Вінницький національний аграрний університет

The paper considers the problem of reducing the drive power of the mechanism for separating stalk feed from trench storages by the batch method by developing and substantiating the parameters and operating modes of the hydraulic drive system. The structure and principle of construction of a system of hydraulic drives of the mechanism for separating a portion of stem feed are proposed. This will significantly reduce the power of the used hydraulic motors by simultaneously controlling the cutting speed of the monolith of stem feed and the feed of the cutting device.

The analysis of changes in the physical and mechanical properties of stalk forage (silage and haylage), depending on the height of occurrence in the trench storage, has been carried out.

The process of separation of the stalk feed from the feed monolith is considered. The complexity of the technological process of separating the portion of the stalk feed from the feed monolith due to the change in the physical and mechanical properties of the feed from the height in the trench storage and the lack of adaptation of the loader drive to such differences is indicated.

A basic hydraulic diagram of the loader drives is proposed, which is based on the dependence of the cutting force of the material on the parameters of cutting modes. The theoretical foundations of the calculation were formulated by I. Timme and later adapted to the peculiarities of the work of agricultural machinery by V.P. Garyachkin. This theory allows you to determine the cutting force on the working body of the cutter bar depending on the cutting speed, feed of the cutter bar and depth of cut.

An adaptive hydraulic drive of the mechanism for separating the stalk feed is proposed, which makes it possible to coordinate the operation of the cutter bar drive with its supply. The possibility of reducing the drive power of the mechanism for separating the stalk feed to 5-6 kW when using a system of hydraulic drives with a mechanism for adapting the working bodies to their working conditions has been confirmed.

The modes of operation and the possibilities of increasing energy efficiency, competitiveness of technological machines and aggregates of the agro-industrial complex, by developing and substantiating the parameters of the hydraulic drive system, are indicated.

Key words: stalk feed, moisture, density, drive, cutting, blade, hydraulic motor, hydraulic cylinder, power.

F. 8. Table. 1. Fig. 11. Ref. 15.

1. Introduction

The current state of the development of agricultural technology provides for a further increase in the level of hydrophysical reasons for working bodies. One of the directions of development of hydraulic drives is to reduce the size of its elements. As a result of these changes, the pressure level of the working fluid in the hydraulic systems rises to 500 bar and more. This, in turn, requires research to improve the design of hydraulic machines and other devices that are part of hydraulic systems [1,2].

The development of agricultural production technologies has led to the emergence of new types of machines. In turn, this process stimulated the expansion of the use of hydraulic drives and the creation of new hydraulic systems with an increased level of technical characteristics.

Creation of new and improvement of existing loaders for stalk feed from trench storage facilities is possible through the rational use of the physical and mechanical properties of feed monoliths. According to the definition of academician V.A. Zheligovsky, three elements take part in any technological process: material, which is the object of research; tool, or working parts of the machine that act on this material; the energy with which the working bodies are activated [3].

Therefore, knowledge of the physical and mechanical properties of the material and taking into account the structural performance of the working body is a prerequisite for the research and development of any machine, including a stalk loader. And the study of the influence of these parameters on the quality of the drive with automatic control makes this study modern and relevant.

The purpose of the work is to study the influence of the physical and mechanical properties of the stem feed and the structural performance of the working body on the quality of work and the drive power of the mechanism for isolation.

2. Analysis of recent research and publications

The problem of mechanizing the unloading of stalk feed from trench storage has been around for a long time. Therefore, there is a fairly large number of designs and developments of loaders of continuous and periodic action, research on the study of the peculiarities of the interaction of working bodies with material, substantiation of their geometric and kinematic parameters. But nevertheless, the issues of reliability, an increase in the service life and the creation of an energy-saving drive for these machines [4] are relevant.

For unloading stalk feed from trench storages, different types of structures of working bodies are used, which are located on the front hitch of the tractor (fig. 1). The most widespread are the working bodies of the cutting type, due to the simpler operating conditions and maintenance.

The development and substantiation of the parameters of working bodies for block loading of stalk forage (silage and haylage) with cutting bodies are devoted to the works of V.V. Krasnikov, V.F. Dubinin, V.G. Popov, A.A. Tolkalov, A.R. Makarov., Pirkelmann H., Maier L. and others [5-7].

*a**b**c**d*

Fig. 1. Loaders of stalk feed from a silage trench:
a – milling working body Nortec (USA), *b* – cutting grip V-LOAD Shear (Nimechchnina),
c – forage cutter V-Load Cutter BVL (Germany), *d* – feed mixer Trioliet Triotrac M (Netherlands)

Academician V.P. Goryachkin developed the foundations of the scientific theory of cutting devices [8]. The works of L.P. Kramarenko and experimental research Karpenko O.M. formed the basis of the standard for cutting devices [9]. Technological foundations for sliding cutting were developed by V.A. Zheligovskiy [10].



V.P. Garyachkin, I.F. Vasilenko, A.I. Ishlinskiy[8], N.V. Sablik and V.N. Gyacheva proposed a different approach and method for the analytical determination of the cutting speed of the stalks of agricultural plants. Their work is devoted to the study of the possibility of using grooved segments for cutting devices of mowers [9]. Bosoy E.S. conducted a study of a cutting knife, the edge of which lost balance in the form of a wedge with a straight, convex and concave chamfer. Research by N. Reznik are aimed at generalizing the scientific, theoretical and experimental foundations of the process of cutting with a blade [3].

It should be noted that the cutting process is the most common type of destruction of agricultural materials [3, 8, 10]. It is from him that the features and design parameters of the cutting elements determine the energy consumption for the technological process of unloading the stalk feed and the performance of the loader. Cutting stem feed is a complex mechanical process in which material properties such as elasticity and viscosity are of paramount importance. The presence of such phenomena as relaxation and creep in silage and haylage makes it possible to classify these materials as elastic-binder materials. They are tissues formed by a spatial fibrous system, the voids of which are filled with liquid and gas. During deformation, the fibers of the material are pressed against the rare and gaseous medium that surrounds them, forcing it to move into less stressed zones. For elastic - binding materials, the characteristic dependence of deformation not only on its size, but also on the rate at which it develops [8].

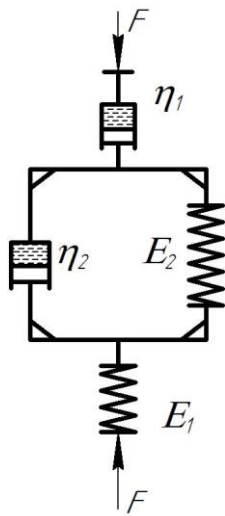


Fig. 2. Rheological model of plant material

On the diagrams that characterize the properties of the material, elasticity is depicted in the form of a spring, the deformation of which obeys Hooke's law, and viscosity - in the form of a cylinder with a viscous fluid [3, 8, 10]. Here the movement of the piston is described by Newton's law. Sequential and parallel connection of the given elements allow simulating the deformation of materials with complex properties. Elastic - binding properties of the considered forage massifs can be most fully characterized by a physical model, which contains three series-connected elements (fig. 2). The proposed model quite fully reflects the picture of the circulation of fibrous plant materials under stress. It includes the element E_1 of instant elasticity, the element E_2 of retarded elasticity, connected in parallel with the viscosity element 2, the flow element 1, connected in series with the first two.

This model makes it possible to explain the essence of the deformation process of elastic - binding materials under load. With a fast loading of the model, its complete deformation occurs mainly due to the compression of the spring - element E_1 . When fixed in a compressed state, the spring E_1 moves the piston of the element η_1 . As the piston progresses, the spring E_1 expands and the stress decreases. This is a typical stress relaxation pattern at constant strain.

The additional load at the initial moment of time causes rapid deformation due to the compression of the spring of the element E_1 , and then - gradual deformation due to the compression of the spring of the element E_2 together with the movement of the piston of the element η_2 . When the load is removed, the spring of element E_1 will be released instantly, and E_2 can only be released gradually, acting on the piston of element η_2 . The position of the piston of element η_1 will fix the permanent deformation.

The rheological model makes it possible to explain the nature of the behavior of elastic-binding materials in the process of their loading and to represent the process of interaction of the edge and bevels of the blade with the material, especially taking into account the cutting speed.

When cutting with a blade, a new surface is formed directly in the area of contact of the cutting edge with the material. The separation of the material into parts under the action of the blade transfers the process of the previous compression of the material by it to the occurrence of a breaking stress G_p . The moment of its occurrence is determined by the value of the critical cutting force F_{cr} applied to the knife. When cutting elastic - binding materials, the force F_{cr} , at which the process of compression of the material is completed and its cutting begins, is the maximum of all the forces that arise during the cutting process. The conditions under which the cutting force takes on the value of F_{cr} are critical. When the blade interacts with the material, the force F_{cr} becomes the most important.

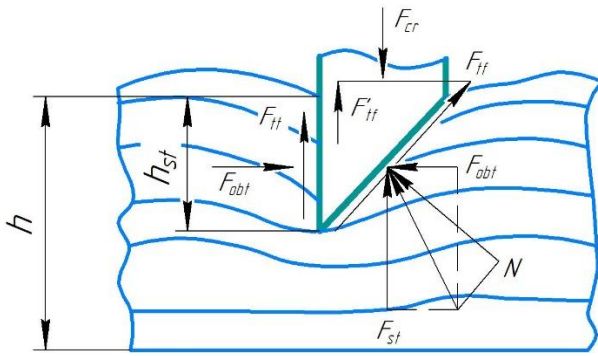


Fig. 3. Forceful interaction of the blade with the material

The force N acts on the edge of the blade, which is the sum of the projections of the forces F_{st} and F_{obt} on the direction of the normal:

$$N = F_{st} \sin \beta + F_{obt} \cos \beta \quad (1)$$

The friction force F_{tf} arises from the force on the chamfer

$$F_{tf} = Nf, \quad (2)$$

where $f = \tan \varphi$ – coefficient of friction of the material against the edge of the blade, φ – is the angle of friction.

Similarly, the friction force F_{tt} arises on the back side of the blade from the force F_{obt} :

$$F_{tt} = F_{obt} f. \quad (3)$$

Force F_{tt} is directed vertically upwards, and F_{tf} – at an angle β of inclination of the edge of the blade. The vertical projection of the force F_{tf} is equal to

$$F'_{tf} = F_{tf} \cos \beta \quad (4)$$

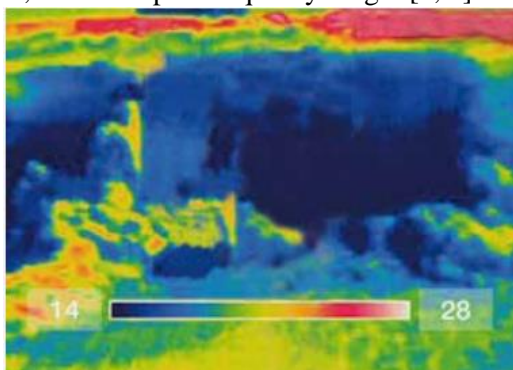
Substitute the value N from expression (1) into expression (2), we get

$$F_{mf} = f \left(F_{st} \frac{1}{2} \sin 2\beta + F_{obt} \cos^2 \beta \right) \quad (5)$$

At the moment of the beginning of cutting, a critical force is applied to the knife, must overcome the sum of all forces that act in the vertical direction:

$$F_{kr} = F_{st} + F_{obt} + F_{tt} + F'_{tf}. \quad (6)$$

The quality and nutritional value of the feed left in the trench also depends on the work of the cutting body of the stalk loader. Therefore, the cutting body, after acting on the feed monolith, must leave an equal and not ripped surface, which will exclude the appearance of secondary fermentation of the feed. In the presence of this process in the forage mass, it is intensely heated, which leads to the loss of energy in the form of heat and the forage becomes less tasty for farm animals. Smoothly cut stalk feed during unloading retains its firm, stable shape and quality longer [4, 5].



a



b

**Fig. 4. Quality indicators of the cutting apparatus of the stalk feed loader:
a – decrease in feed heating, b – preservation of feed density**

The work of the cutting bodies of stalk feed loaders, made in the form of knives, takes place in difficult conditions of squeezing them by the forage mass, different mechanical-physical-mechanical properties of the



feed, which vary both in depth and in width, and research of such cutting bodies is not enough. This restrains the level of developments in the mechanization of loading and unloading operations in the extraction of stalk feed.

3. Research results

In the context of the urgent need to increase the energy efficiency and economic efficiency of agricultural machines, the directions of creating means of mechanization of operations, the separation and unloading of stem feed, in which the principle of adaptation of the work of executive hydraulic drives to the conditions of their load is implemented [1, 9].

The use of this principle of regulating the operating modes of the hydraulic drive system will significantly reduce the power of the executive hydraulic motors, as well as reduce the loss of time during stops caused by overloads of the cutting mechanisms.

The energy efficiency of most industrial hydraulic systems depends, first of all, on two factors - the circuit design and the type of pumping unit and the operating modes of the actuators [1, 2, 5, 9].

The study of the physical and mechanical properties of the stem feed and the design and technological parameters of the working body was carried out at the branch named after V.I. Michurina ZAO Zernoprodukt MHP, Vinnytsia region, Khmel-growing region during 2018-2020 in ground silos. The shelf life of the stem feed was 3 to 9 months.

Stem feeds stored in trench storage are characterized by botanical and fractional composition, density and moisture content, which vary in width and depth, and in turn affect the operation of the separation mechanism [11, 12]. Therefore, the program for the study of the physical and mechanical properties of stem feed is provided to investigate:

- moisture content of stem feed in the trench storage;
- the density of the feed in the trench;
- fractional composition of the mass.

The study of these properties was carried out directly in trench storages, since, as the experience of working with piles of stem feed shows, it is practically impossible to cut out a block of feed for laboratory studies of its physical and mechanical properties without changing its internal connections, and carrying out this research leads to distortion results.

To determine the moisture content and fractional composition of the fodder monolith, an average fodder sample was taken. Stem feed (silage, haylage) was taken from the trench in small portions from different sections of the cut of the forage massif. After that, it was mixed and an average sample weighing 1000 g was taken for research [11].

The study of physical and mechanical properties was carried out according to DSTU 4782-2007 [12]. When conducting studies of physical and mechanical properties, the culture from which the feed was prepared, the phase of its development, moisture and bulk density, the fractional composition with the distribution of particles into classes - less than 3 were noted; 3,1-5; 5,1-7; 7,1-10; 10,1-12; 12,1-15; 15,1-20 mm and more than 20 mm (fig. 5).

The distribution of the fractional composition of the crushed mass into the classes given in table 1.



a



b

Fig. 5. Shredded mass with a theoretical rod length of 5 mm (a), with a theoretical rod length of 20 mm (b)

It should be noted that today's forage harvesters allow you to regulate the degree of crushing of green mass within wide limits, which excludes additional crushing of the stalk feed before feeding [13].



Table 1

Distribution of fractional composition into particles

Particleclass (length, mm)	1 – sample		2 – sample		3 – sample		Average value	
	Weight, g	%	Weight, g	%	Weight, g	%	Weight, g	%
Less than 3	57	4,07	30	3,0	52	5,2	46,33	4,09
3,1–5	72	5,14	37	3,7	49	4,9	52,67	4,58
5,1–7	154	11,00	90	9,0	125	12,5	123,00	10,83
7,1–10	356	25,43	232	23,2	210	21,0	266,0	23,21
10,1–12	314	22,43	217	21,7	233	23,3	254,67	23,55
12,1–15	136	9,72	151	15,1	132	13,2	139,66	12,67
15,1–20	149	10,64	143	14,3	98	9,8	130,0	11,58
More than 20	162	11,57	100	10,0	101	10,1	121,0	9,49
Sampleweight, g	1400	100	1000	100	1000	100	1133,3	100

According to GOST 4782-2007, the moisture content of the silage mass was determined by this method. The weighing bottle was hung up to 5 g of chopped feed and dried in an oven at 130°C for 40 minutes. After drying and cooling in an exsicator, the weighing bottles were weighed again and the moisture content of the mass was determined according to the difference in weight before and after drying according to GOST 27548-87 according to the formula [11]

$$W_B = \frac{m - m_n}{m} \cdot 100, \quad (7)$$

where m – is the mass of the sample before drying, g; m_n – is the mass of the sample after drying, g.

Figure 6 shows the change in the moisture content of the stem feed from the height H of bedding in the storage, from which it can be seen that the moisture content of the forage at the base is higher than in the upper layers of the forage monolith. An increase in the moisture content of the stalk feed in the lower layers has a positive effect on the operation of the loader cutterbar, since excess moisture in the feed reduces the friction of the moving elements.

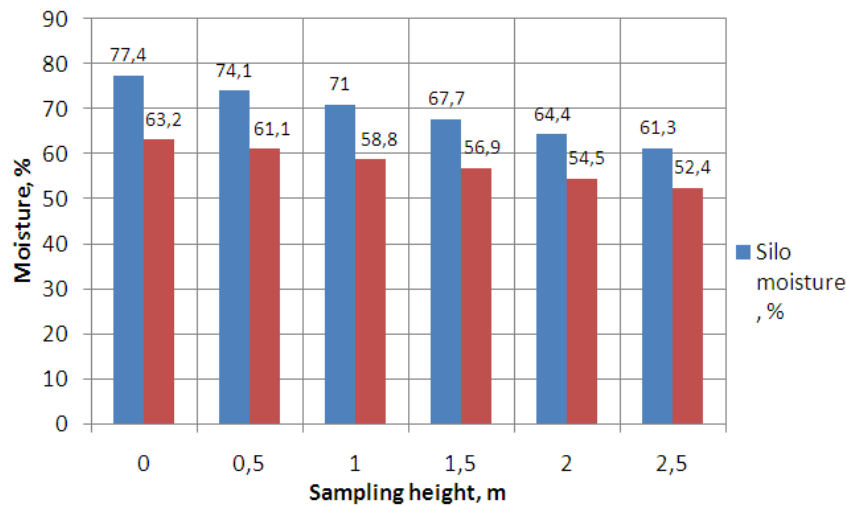


Fig. 6. Changes in feed moisture at bedding height

The density of the forage monolith was determined as follows: a 100 × 50 × 20 cm metal box without a bottom (volume 0.1 m³) was placed on the compacted mass. Then the mass was chosen from its inner side until the box settled to the upper edge and weighed on a balance and the density was determined according to the well-known formula [11].

$$\rho = \frac{m}{V}, \quad (8)$$

where ρ – is the density of the silo, kg/m³, m – is the mass of the cube, kg, V – is the volume of the cube, m³.

The density of the stem feed, as well as the moisture, varies from the base to the upper layers of the feed, which can be seen from fig. 7.



When using a double knife [6], the change in the drive power of the cutting mechanism occurs according to the response surface shown in fig. 8. According to the dependences shown, the power of the double knife drive increases with increased feed rates, and with an increase in feed from 0.018 m/s to 0.028 m/s, the double knife drive power required to create an effective cutting force increases by more than 2.5 times.

At the same time, the research results of I.G. Pavlova testify that with an increase in the cutting speed (frequency of rotation of the drive motor) from 3 to 8 r/s, the level of the knife drive power can be reduced from 5,5 kW to 4,75 kW (at a feed rate of 0,028 m/s) [7].

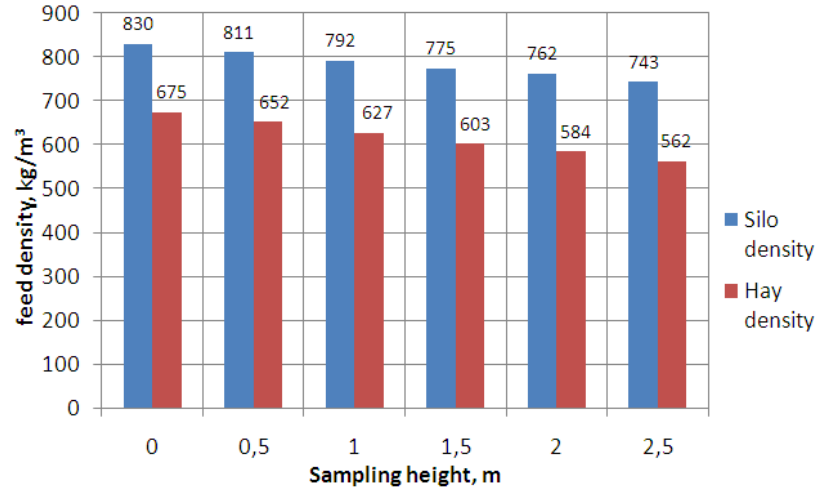


Fig. 7. Change in density of feed depending on the height of the storage

At the same time, the power of the double knife feed drive, while ensuring the rational performance of the stalk loader (feed rate 0,02 – 0,028 m/s), varies within 0,1 – 0,8 kW.

It should be noted that the required power according to the one shown in fig. 8 of the graph can be reduced to 2 kW depending on the feed rate and the rotation frequency.

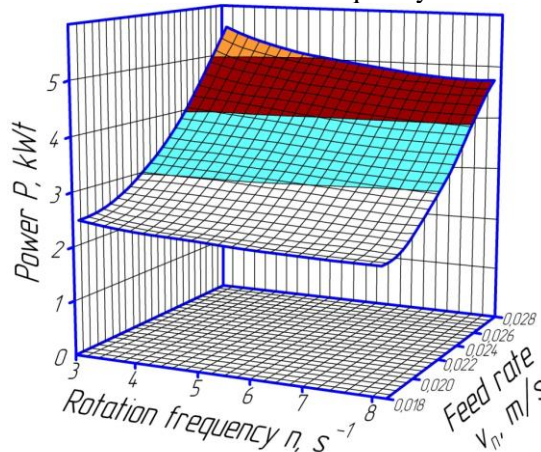


Fig. 8. Double knife drive power

The recommended operating modes of the mechanism for the separation of stalk feed provide for fixed values of the cutting speed and feed rate, in fact, without providing for a possible significant increase in cutting forces when corn rosettes and other inclusions of increased hardness fall under the knife (or changes in the physical and mechanical properties of feed along the height of occurrence). Obviously, it is these circumstances that are the reason for the increase by foreign manufacturers of the drive power of the cutting mechanism and the feed drive of the U – like frame. Their total capacity in machines manufactured by European leading firms is 20 to 25 kW.

The indicated fact of a significant excess of the power of the movers of the mechanisms for isolating the stalk feed over the theoretically and experimentally substantiated values of the required power of the movers indicates the need to improve the system of hydraulic drives of loaders. The direction of improvement should provide for the coordination of the regulation of the cutting speed and feed rate in order to stabilize the total power of these reasons, which will provide a significant energy-saving effect.



To reduce the energy consumption of the hydraulic drive system of the mechanism for separating stalk feed, the structure and construction principle of the hydraulic drive system was developed, which allow realizing the effect of a significant reduction in the power of the drive hydraulic motors by adapting their operating modes to the state of the technological system [14, 15].

A schematic diagram of the hydraulic drive system of the mechanism for separating stalk feed, developed according to the above, is shown in fig. 9.

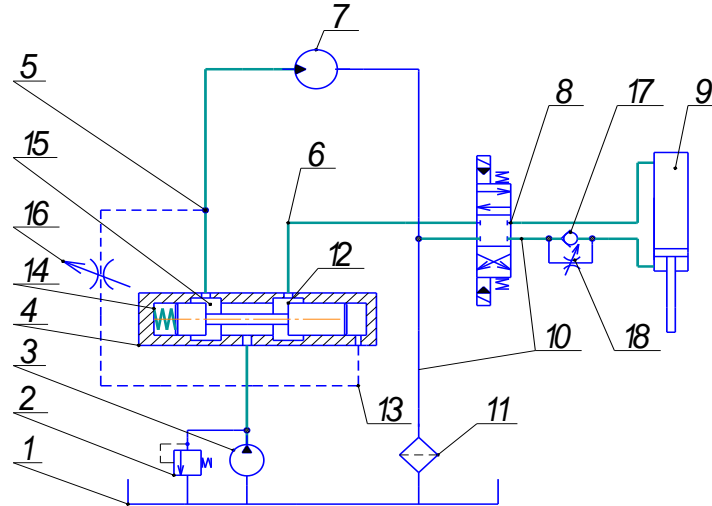


Fig. 9. Hydraulic diagram of the hydraulic drive system of the mechanism for separating stalk feed

The principle of operation of this system provides for the regulation of the U – like frame feed according to the change in the cutting force that acts on the cutting device, as a result of which the energy consumption for the separation of the block portion of the stalk feed is stabilized with fluctuations in the parameters that determine the characteristics of the cutting process.

The drive system of the mechanism for separating stalk feed contains a hydraulic tank 1, a safety valve 2, a hydraulic pump 3, a spool flow divider 4 with a control line 13, a controlled spool 12, a hydraulic motor 7, a high pressure hydraulic line 5,6, a three-line three-position valve with electro-hydraulic control 8, hydraulic cylinder 9, hydraulic drain lines 10, filter 11, check valve 17, throttle 16,18 and spring 14 (fig. 9).

The proposed use of a flow divider 4 between the cutting mechanism 7 and the feed hydraulic cylinder 9 makes it possible to coordinate a decrease in its feed with an increase in the load on the cutter, which in turn leads to a decrease in the cutting force (fig. 10). At the same time, this increases the supply of working fluid to the cutter bar drive hydraulic motor, which also helps to reduce the cutting force and the required power of the cutter bar hydraulic drive.

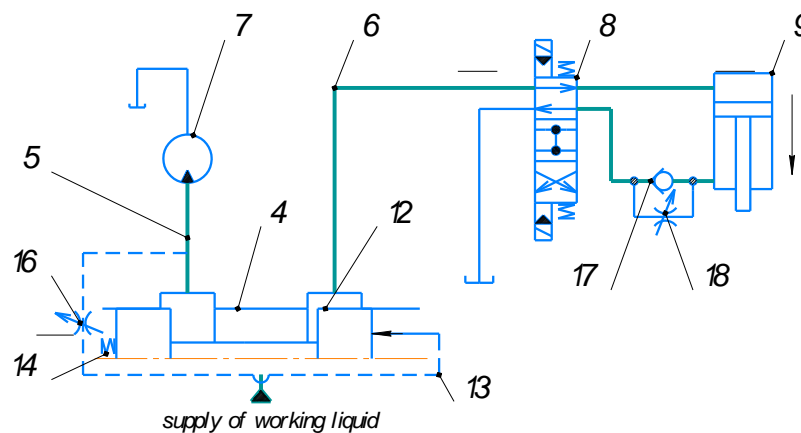


Fig. 10. Adjustment of giving at increase of the mechanism for separation on the cutting device of the loader of stalk forages

At the same time, as the cutting force decreases, the distributor reduces the supply of working fluid to the hydraulic motor of the cutting device and accordingly increases its supply to the hydraulic cylinder of the cutting drive, which allows to reduce the cutting force of the stalk feed monolith.



One of the effective tools for the implementation of this task is the reasonable application of modern calculation methods, optimal and automated design with further modeling of the main processes, as well as a multifactor experiment.

Figure 11 shows the obtained as a result of mathematical modeling of the adaptive system of the hydraulic drive of the mechanism for separation of stem forages using the software product MathCad.

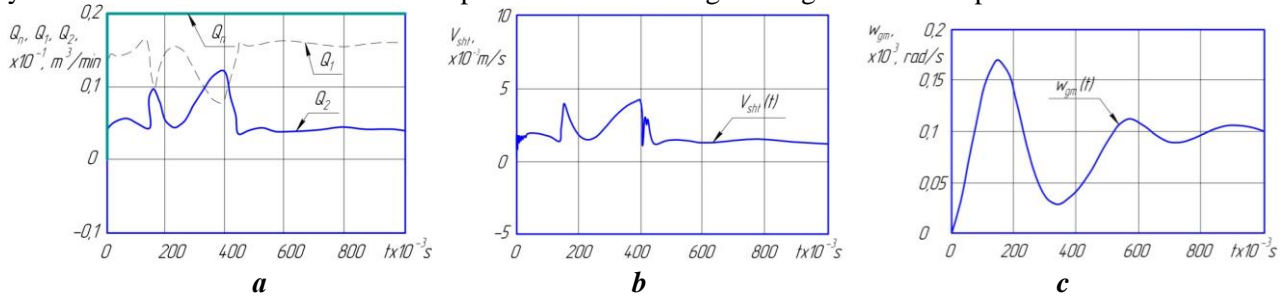


Fig.11. Transient operation of the hydraulic drive system the mechanism for separation of stalk forages at change of loading on the cutting device:

a – expenses of liquid which are consumed by the pump (Q_n), the hydraulic motor (Q_1) and the hydraulic cylinder (Q_2); b – changing the feed rate of the U-shaped frame by the hydraulic cylinder; c – change in the angular velocity of the hydraulic motor

Transients are calculated at the following initial values of parameters of system of hydraulic drives of the mechanism for separation of stalk forages: $Q_n=2,38 \cdot 10^{-4} \text{ m}^3/\text{s}$, $a=0,5 \text{ mm}$; $l_1=6 \text{ mm}$, $l_2=2 \text{ mm}$; $\mu=0,62$; $p_0=10,0 \text{ MPa}$; $\rho=850 \text{ kg/m}^3$; $K=0,6 \cdot 10^{-9} \text{ m}^2/\text{N}$, $d_{zoi}=27 \text{ mm}$; $I=100 \text{ kg} \cdot \text{m}^2$; $m_{pr}=45 \text{ kg}$; $\beta=2,5 \cdot 10^3 \text{ N} \cdot \text{s}$; $D_{ts}=63 \text{ mm}$; $W_1= W_2= W_4=100 \text{ cm}^3$; $W_3=25 \text{ cm}^3$; $b_1=1 \text{ mm}$; $b_2=2 \text{ mm}$; $C_{pr}=0,5 \text{ N/mm}$.

Here we denote: Q_n – pump flow, a – width of the working edge of the controlled spool I_2 , l_1 – spool stroke to the right, l_2 – spool stroke to the left, μ – flow rate, p_0 – initial value of pump pressure, ρ – density of the working fluid, K is the coefficient of compressibility of the working fluid, d_{zoi} is the diameter of the controlled spool, I is the moment of inertia on the hydraulic motor shaft, m_{pr} is the reduced mass, β is the coefficient of binding friction, D_{ts} is the diameter of the hydraulic cylinder, W_1, W_2, W_3, W_4 are the volumes of the system, b_1, b_2 – the distance to the stops that limit the movement of the spool, C_{pr} – the stiffness of the spring of the controlled spool.

As a result of mathematical modeling of work of adaptive system of hydraulic drives of the mechanism for separation of stalk forages the possibility of adaptation of working bodies to conditions of their work is proved. The transient process (fig. 11), which occurs when starting the adaptive hydraulic system of the block-batch separator, is completed fairly quickly. By four hundred milliseconds with access to stable values - the system works steadily. Moreover, in this case, the system of hydraulic actuators in the start-up process reaches the level of the value of the supply of working fluid to the hydraulic motor and the hydraulic cylinder of the supply U – like frame $Q_1 = Q_2 = 0.10 \times 10^{-1} \text{ m}^3/\text{min}$ (fig. 11, a).

After loading the initial parts of the hydraulic motors with the cutting moment and the feed force for 400 ms, the transient process also has the character of damping, which indicates that the hydraulic drive system does not lose stability under load, but there is a change in fluid supply to the hydraulic motor $Q_1 = 0.16 \times 10^{-1} \text{ m}^3/\text{min}$. (increases by 50 %), and the supply of working fluid to the hydraulic cylinder of the feed drive U – like frame decreases to the value of $Q_2 = 0.05 \times 10^{-1} \text{ m}^3/\text{min}$, which corresponds to a decrease in the feed rate by 50 %. In this case, the angular velocity of the hydraulic motor shaft increases to the value of $\omega_{gm} = 0.1 \times 10^3 \text{ rad/s}$ (fig. 11, c), and the feed rate of the U – like frame decreases to $V_{sht} = 2.8 \cdot 10^{-3} \text{ m/s}$.

Thus, it is shown that in this case the possibility of implementing the principle of interconnected control of the parameters of the cutting mode – speed and feed of the cutting tool when changing the cutting force, which determines the load on the hydraulic motor shaft of the cutting tool. Reducing the supply of U – like frame while increasing the speed of the motor according to the laws that determine the cutting force on the cutting tool, should reduce the load on the drive motors and thus stabilize the value of power required to separate the block portion of the stem feed.

Proportional changes in the speeds of the working bodies – the hydraulic motor of the cutting device and the hydraulic cylinder of the drive U – such a frame, under certain conditions may not always provide a proportional change in cutting force, which is determined by the dependence of cutting force on cutting and feed speeds.



Working bodies of agricultural machines requires further research, which should show directions for solving the problem of reducing the impact of load instability of the working bodies on the energy-saving properties of agricultural machine drives.

4. Conclusion

Effective operation of the loader of stalk forages is possible only at the conditions of the maximum adaptation to technological process and physical and mechanical properties of the unloaded forage. Experimental studies of physico-mechanical and technological properties of feed monoliths allow to establish:

- with increasing height of the massif, the density of stem forages decreases (silage from 830 kg/m³ in the base to 743 kg/m³ at a height of 2,5 m and haylage from 675 kg/m³ in the base to 562 kg/m³ at a height of 2,5 m).

- humidity also varies from the height of the silage from 77 to 61 %, haylage from 63 to 53 %.

The power of the double knife drive increases with increased feed speeds, and when the feed increases from 0.018 m/s to 0.028 m/s, the power of the double knife drive required to create an effective cutting force increases more than 2,5 times.

Therefore at design of loaders of stalk forages it is necessary to consider physical and mechanical properties of forage as their change leads to disturbance and temporary overloads of hydraulic system of the loader; constructive executions of working bodies which directly influence power of a drive of the loader of stalk forages.

References

- [1] Shmat, S.I., & Luzan, S.V., & Kolisnyk, S.V. (2010). Tendentsii stalogo rozvytku suchasnogo silskogospodarckogo mashyno-buduvannia v Ukraini i za rubiezem [Product innovative policy]. [Trends in Sustainable Development of Modern Agricultural Machinery in Ukraine and Abroad]. Retrieved from <http://dspace.kntu.kr.ua/jspui/handle/123456789/4971>. /KNTU.–2010 [in Ukrainian].
- [2] Ratushna, N., & Mahmudov, I., & Kokhno, A. (2007). Metodichni pidkhody do stvorennia novoi silskokhospodarskoi tekhniki u vidpovidnosti z vymohamy rynku naukoiemnoi produktsii [Methodical approaches to the creation of new agricultural machinery in accordance with the demands of the market of science-intensive products]. *MOTROL– MOTROL*, 9. 119–123 [in Ukrainian].
- [3] Reznik, N. (1975). *Teoriya rezaniya lezvyem i osnovy rascheta rezhushchikh apparatov*. [Theory of cutting with a blade and the basics of calculating the cutting apparatus]. Moscow: Mashinostroenie [in Russian].
- [4] Rutkevych, V.S. (2010). Suchasnyi stan mekhanizatsii vyvantazhennia konservovanykh kormiv [The current state of mechanization of unloading of canned food]. *Zbirnyk naukovykh prats VNAU – Collection of scientific works of VNAU*, 4. 87–95 [in Ukraine].
- [5] Rutkevych, V.S. (2017). Adaptivnyi hidravlichnyi pryvod blochno-portsiinoho vidokremliuvacha konservovanoho kormu [Adaptive hydraulic drive block-portable of canned forage block-batch separator]. *Tekhnika, enerhetyka, transport APC*. 4, 108113 [in Ukraine].
- [6] Dubinin, V. F. (1994). Obosnovanie protsessov i sredstv pohruski obektov selskokhoziaistvennogo proizvodstva [Substantiation of processes and means of loading of objects of agricultural production]. *Extended abstract of candidates thesis. Moskva*. [in Russian].
- [7] Pavlov, I.M. (1990). Sovershenstvovanie tekhnolohicheskoho protsessa i obosnovanie parametrov rabocheho orhana pohruzchuka dlia blochnoi vyemki konservirovanykh kormov iz transheinykh khranilishch [Improvement of technological process and substantiation of parameters of a working body of the loader for block excavation of canned forages from trench storages]. *Extended abstract of candidates thesis. Saratov*. [in Russian].
- [8] Horiachkin, V.P. (1968). Sobranie sochinenii. V 3 t. T.3. Teoriia solomarezki i silosarezki [Collection of works. In 3 vols. Vol.3. Theory of straw chopper and silage cutter]. Moskva: Kolos [in Russian].
- [9] Voitiuk, D.G. & Ytsun, S.S., & Dovzhyk, M.Y. (2008). *Silskogospodarcki mashyny: Osnovy teorii i rozrakhunku*. [Agricultural machines: the basics of theory and calculation:]. Sumy: VTD “Universytetska knyga” [in Ukraine].
- [10] Zhelihovskii, V.A. (1940). *Eksperimentalnaia teoriia rezaniia lezviem* [Experimental theory of blade cutting]. Moskva: Trudy MIMESKh [in Russian].



- [11] Tsarenko, O., Yatsun, S., Dovzhik, M. & Oliynik, G. (2016). *Mekhaniko-tehnologichni vlastyivosti sil's'kohospodars'kykh materialiv [Mechanical and technological properties of agricultural materials]*. Kyiv: Ahrarna osvita [in Ukrainian].
- [12] Sylos iz zelenikh roslyn. Tekhnichni umovy. DSTU 4782:2007. (2009). Kyiv: Derzhspozhyvstandart. [in Ukrainian].
- [13] Kuzmenko, V. F., Yampolsky, S. M. & Maksimenko, V. V. (2014). Eksperymentalne vyznachennya fraktsiynoho skladu masy kukurudzy pry zahotivli sylosu u pizni stroky [Experimental determination of fractional composition of corn mass during silage preparation in late terms]. *Mekhanizatsiya ta elektrifikatsiya silskoho hospodarstva: mizhvid. temat. nauk. zb. – Mechanization and electrification of agriculture: intersectionality. theme. of sciences. Sat*, 99, 559–568 [in Ukrainian].
- [14] Chubyk, R.V. & Zelinskyi, I.D. (2015). Identyfikatsiia kryteriiv dlia enerhozberihaiuchoho keruvannia vibropriy-vodamy adaptyvnykh vibromashyn [Identification of criteria for energy saving control of vibration drives of adaptive vibrating machines]. *Avtomatyzatsiia vyrobnychkykh protsesiv u mashynobuduvanni ta prykladobuduvanni – Automation of production processes in machine building and instrument making*, 49. 107–111 [in Ukrainian].
- [15] Pat. KM 80958 Ukraina. (2013). Hidravlichnyi pryvod blochno-porziinogo vidokremliuvacha konserovanykh kormiv [The hydraulic drive of the block-portion separator of canned forages]. *Publ.* 10.06.2013 [in Ukrainian].

ВПЛИВ ФІЗИКО-МЕХАНІЧНИХ ВЛАСТИВОСТЕЙ СТЕБЛОВОГО КОРМУ ТА КОНСТРУКТИВНОГО ВИКОНАННЯ РОБОЧОГО ОРГАНУ НА ПОТУЖНІСТЬ ПРИВОДА МЕХАНІЗМУ ДЛЯ ВІДОКРЕМЛЕННЯ

Розглядається проблема зменшення потужності привода механізму для відокремлення стеблових кормів з траншейних сховищ порційним методом шляхом розробки та обґрунтування параметрів системи гідравлічних приводів. Запропоновано принципово нову побудову системи гідроприводів механізму для відокремлення стеблового корму, яка дозволяє зменшити потужність виконавчих гідродвигунів (гідромотора та гідроциліндра) за рахунок одночасного регулювання швидкості різання моноліта стеблового корму та подачі різального апарату.

Проаналізовано зміни фізико-механічних властивостей стеблового корму (силосу та сінажу) в залежності від висоти залягання в траншейному сховищі.

Розглянуто процес відокремлення стеблового корму від кормового моноліту. Зазначено складність технологічного процесу відокремлення порції стеблового корму від кормового моноліту за рахунок зміни фізико-механічних властивостей корму від висоти залягання в траншейному сховищі та відсутність адаптації привода навантажувача до таких перепадів.

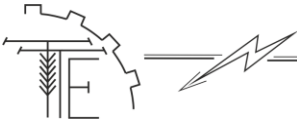
Запропонована гідравлічна система приводів механізму для відокремлення стеблового корму, основана на відомій залежності сили різання рослинного матеріалу від параметрів режимів різання, які були основані І.Тіме і в подальшому адаптовані до особливостей роботи сільськогосподарської техніки В.П. Горячкіним, що дозволяють визначити зусилля різання на робочому органі різального апарату при змінних параметрах швидкості різання, подачі різального апарату та глибини врізання різального апарату.

Запропоновано адаптивний гідравлічний привод механізму для відокремлення стеблового корму, який дозволяє узгодити роботу привода різального апарату з його подачею. Підтверджено можливість зменшення потужності привода механізму для відокремлення стеблового корму до 5-6 кВт при використанні системи гідравлічних приводів з механізмом адаптації робочих органів до умов їх роботи.

Зазначені режими роботи та можливості підвищення енергоефективності, конкурентоспроможності технологічних машин і агрегатів АПК, шляхом розробки та обґрунтування параметрів системи гідравлічних приводів.

Ключові слова: стебловий корм, механізму для відокремлення, вологість, щільність, привод, різання, лезо, гідромотор, гідроциліндр, потужність.

Ф. 8. Таб. 1. Рис. 11. Літ. 15.



ВЛИЯНИЕ ФИЗИКО-МЕХАНИЧЕСКИХ СВОЙСТВ СТЕБЕЛЬНЫХ КОРМОВ И КОНСТРУКТИВНОГО ИСПОЛНЕНИЯ РАБОЧЕГО ОРГАНА НА МОЩНОСТЬ ПРИВОДА МЕХАНИЗМА ДЛЯ ОТДЕЛЕНИЯ

Рассматривается проблема уменьшения мощности привода механизма для отделения стеблевых кормов с траншейных хранилищ порционным методом путем разработки и обоснования параметров системы гидравлических приводов. Предложено принципиально новое построение системы гидроприводов механизма для отделения стеблевого корма, которая позволяет уменьшить мощность исполнительных гидродвигателей (гидромотора и гидроцилиндра) за счет одновременного регулирования скорости резки монолита стеблевого корма и подачи режущего аппарата.

Проанализированы изменения физико-механических свойств стеблевого корма (силоса и сенажа) в зависимости от высоты залегания в траншейном хранилище.

Рассмотрен процесс отделения стеблевого корма от кормового монолита. Отмечено сложность технологического процесса отделения порции стеблевого корма от кормового монолита за счет изменения физико-механических свойств корма в зависимости от высоты залегания в траншейном хранилище и отсутствие адаптации привода погрузчика к таким перепадам.

Предложенная гидравлическая система приводов механизма для отделения стеблевого корма, основанная на известной зависимости силы резания растительного материала от параметров режимов резания, которые были основаны I.Тиме и в дальнейшем адаптированы к особенностям работы сельскохозяйственной техники В.П. Горячкина, позволяющие определить усилие резания на рабочем органе режущего аппарата при переменных параметрах скорости резания, подачи режущего аппарата и глубины врезки режущего аппарата.

Предложен адаптивный гидравлический привод механизма для отделения стеблевого корма, который позволяет согласовать работу привода режущего аппарата с его подачей. Подтверждена возможность уменьшения мощности привода механизма для отделения стеблевого корма до 5-6 кВт при использовании системы гидравлических приводов с механизмом адаптации рабочих органов к условиям их работы.

Указанные режимы работы и возможности повышения энергоэффективности, конкурентоспособности технологических машин и агрегатов АПК путем разработки и обоснования параметров системы гидравлических приводов.

Ключевые слова: *стеблевой корм, механизма для отделения, влажность, плотность, привод, резки, лезвие, гидромотор, гидроцилиндр, мощность.*

Ф. 8. Таб. 1. Рис. 11. Лит. 15.

ВІДОМОСТІ ПРО АВТОРІВ

Шаргородський Сергій Анатолійович – кандидат технічних наук, доцент кафедри «Машин та обладнання сільськогосподарського виробництва» Вінницького національного аграрного університету (вул. Сонячна, 3, м. Вінниця, 21008, Україна, e-mail: sergey20@vsau.vin.ua, <https://orcid.org/0000-0003-2125-773X>).

Руткевич Володимир Степанович – кандидат технічних наук, доцент кафедри машин та обладнання сільськогосподарського виробництва Вінницького національного аграрного університету (вул. Сонячна, 3, м. Вінниця, Україна, 21008, e-mail: v_rut@ukr.net, <https://orcid.org/0000-0002-6366-7772>).

Шаргородский Сергей Анатолійович – кандидат технических наук, доцент кафедры «Машины и оборудование сельскохозяйственного производства» Винницкого национального аграрного университета (ул. Солнечная, 3, г. Винница, 21008, Украина, e-mail: sergey20@vsau.vin.ua, <https://orcid.org/0000-0003-2125-773X>)

Руткевич Владимир Степанович – кандидат технических наук, доцент кафедры машин и оборудования сельскохозяйственного производства Винницкого национального аграрного университета (ул. Солнечная, 3, г. Винница, Украина, 21008, e-mail: v_rut@ukr.net, <https://orcid.org/0000-0002-6366-7772>).

Serhiy Shargorodskiy – Ph.D., Associate Professor of the Department "Machinery and Equipment of Agricultural Production" of the Vinnytsia National Agrarian University (3, Solnychna str., Vinnytsia, Ukraine, 21008, e-mail: sergey20@vsau.vin.ua, <https://orcid.org/0000-0003-2125-773X>).

Volodymyr Rutkevych – Ph.D., Associate Professor of the Department of Machinery and Equipment for Agricultural Production of Vinnytsia National Agrarian University (Sonyachna Str., 3, Vinnytsia, Ukraine, 21008, e-mail: v_rut@ukr.net, <https://orcid.org/0000-0002-6366-7772>).