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Contacts

18 B.Khmelnytsky Ave, Melitopol, Zaporizhia obl. 72310, Ukraine
http://www.tsatu.edu.ua
Telephone: +38 (0619) 42-06-18
Fax: +38 (0619) 42-24-11
E-mail: office@tsatu.edu.ua

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Dear readers!

We offer you the first issue of the "Agriculture and Environment" Journal. Agriculture of Ukraine is the most important industry of material production, which meets the continuously growing needs for food and fiber. The overall economic situation of the country depends on agricultural productivity. Meeting the growing demand for high quality agricultural products is necessary for full technological innovation of the industry in order to increase its energy efficiency and environmental safety.

In view of the above, the purpose of our publication is the exchange of scientific views, experiences, hypotheses and achievements of Ukrainian scientists and specialists, foreign universities, research institutions and agricultural producers.

I express my sincere gratitude to the editorial team and authors of the first issue for their active participation in the development of the publication. I invite all colleagues from Ukraine and countries of near and far abroad to participate in the work of the journal.

I wish all authors and readers of the journal success in all of your creative endeavors in scientific research and new achievements within a wide range of knowledge!

STUDY OF A PUSH-PULL PLOUGH COMBINATION

Volodymyr Nadykto[1], Doctor of Engineering, corresponding member of the NAS of Ukraine,
Volodymyr Kyurchev[1], Doctor of Engineering, corresponding member of the NAS of Ukraine,
Hristo Beloev[2], Professor, corresponding member of the AS of Bulgaria,
Alexandr Kistechok[1], PhD in Engineering
[1]Tavria State Agrotechnological University
[2] University of Ruse "Angel Kanchev"

The article presents the results of the study of two plough combinations. One of them included a ХТЗ-16131 tractor, a front-mounted double mouldboard plough and arear-mounted four-furrow plough (*Push-pull* combination '2 + 4').The second combination consisted of the same tractor and five-furrow rear-mounted plough ('0 + 5'combination). According to the experimental data, the working width of '2 + 4' unit was 20.9% higher than the working width of '0 + 5' unit. And although the working speed of the first combination turned out to be 1.5% lower, due to the width advantage the productivity of its work was higher by 19.5%. As a result, the specific fuel consumption of the '2 + 4' unit was lower. Fuel economy made up 11.5 per cent under the conditions of the field experiment. The average square deviation of the ploughing depth in both compared combinations did not exceed agrotechnical requirements (± 2 cm) and made up±1.98 cm for '0 + 5' unit and ± 1.52 cm for '2 + 4' unit. At the same time, the indicated difference between these statistical characteristics (± 1.98 cm and ± 1.52 cm) is not accidental. On these grounds it can be assumed that application of the *Push-pull* '2 + 4'plough combination ensures soil cultivation providing better uniformity of the plough motion in depth.

Keywords: ploughing, combination, push-pull, front-mounted plough, productivity, fuel consumption.

INTRODUCTION

One of the most important tasks of agricultural production is to reduce power inputs on ploughing. The first step in this problem solving is to improve traction of the tractor by increasing its coupling weight.

This can be achieved by using ploughing combinations with the ploughs attached using a *Push-pull* method. According to theoretical studies, due to the vertical component of traction resistance of a front-mounted plough, front wheels load rises. This increases tractor coupling weight. [Nadykto, 1994; Nadykto, Genov, Ayubov, 2003]. As a result, this leads both to a certain decrease in combination slippage and to reduction of specific fuel consumption for the ploughing unit in a whole [Nadykto, 1996].

However, if the front plow is not attached correctly to the power unit, it may not be loaded, but on the contrary the unloading of the tractor front wheels can take place. This causes the inevitable loss of handling and stability of the entire ploughing combination. Theoretical studies have established that in order to avoid this, while using a tractor with 32 kN of traction power, the front-mounted plough should have two bodies and a rear-mounted plough needs four bodies ('2 + 4' combination) [Nadykto, Kistechok, 2015]. The tractor moves in the furrow with its right wheels, the front plough is attached rigidly to the tractor in the horizontal plane, and the supporting wheel of this implement is located outside the furrow.

The purpose of this article is to present and analyze the results of an experimental evaluation of trajectory, traction, power and agrotechnical parameters of the ploughing unit operation according to the *Push-pull* combination with '2 + 4' number of bodies.

MATERIALS AND METHODS

The ploughing unit with '2 + 4' combination consisted of a ХТЗ-16131tractor, front-mounted double-furrow and rear-mounted four-furrow ploughs (Fig. 1a). To compare different combinations '0 + 5' ploughing unit, which included the same tractor and a rear-mounted five-furrow plough ПЛН-5-35 (Fig. 1b), was tested as well.

Contact info: Melitopol, Ukraine, imesh@zp.ukrtel.net

a)

b)

Figure 1. ‘2 + 4’ (a) and ‘0 + 5’ (b) ploughing combinations

Ploughing units specification

Engine power of XT3-16131 tractor, kW	132
Operating weight, kg	8100
Track width, mm	2100
Longitudinal tractor base, mm	2860
The size of front and rear axle tires	16,9R38
Front-mounted plough working widtn, m	0,70
Rare-mounted plough, m	1,40
The working widtn of ‘2 + 4’ ploughing combination, m	2,10
The working widtn of ‘0 +5’ ploughing combination, m	1,75

The following parameters were recorded during field tests:

- soil moisture and density;
- longitudinal and vertical profile;
- traction resistance and working width of ploughs (B_p);
- traverse speed (V_p), wheel slip (δ) and hourly fuel consumption of tractors (G_h);
- ploughing depth.

Soil moisture was determined by means of a widely known *Hot drying* method. A special method as well as a tool has been developed to measure topsoil density [Kuvachov, Nadykto, Kyurchev, 2008]

Oscillations in amplitude and frequency of the field profile unevenness in longitudinal direction (field profile) were measured with the help of a profile recording instrument – profilograph (Fig. 2).

Figure 2. The instrument which recorders field profile unevenness

The tractive resistance of the ploughs was recorded by means of a strain gauge unit designed for a tractive effort up to 40 kN.

The speed of the ploughing unit during operation was fixed by the use of a track wheel mounted on the tractor. Speed counters were installed on the hubs of the track wheel’s front and rear axles. Electric signals were read with the help of current collectors.

To measure the hourly fuel consumption of the tested tractor a pulse-type flowmeter was used. Electrical signals which were being produced by the profilograph, strain gage, trackwheel, speed counters and a fuel gauge were being recorded by a computer after passing through an analog-to-digital converter.

Tractor wheels skidding was calculated by the formula [Nadykto, 2003]:

$$\delta = 1 - \frac{n_{xx}}{n_p} \cdot \frac{V_p}{V_{xx}},$$

where n_{xx}, n_p is rotating frequency of the tractor wheels when the ploughing unit is being moved without the traction load and with it, respectively; V_{xx},V_p is the ploughing unit speed without the traction load and with it, m·s^{-1}.

It was provided that the ploughing units without load moved along the field with ploughs raised into the transport position.

Productivity of the plough combination (W_a, $ha \cdot h^{-1}$) and specific fuel consumption (G_u, $kg \cdot ha^{-1}$) was determined as follows:

$$W_a = 0{,}1 \cdot B_p \cdot V_p;$$
$$G_u = {}^{G_h}/_{W_a}.$$

All the parameters were measured at least 5 times.

RESULTS AND DISCUSSION

Laboratory and field studies were carried out in a field with the following parameters: soil moisture content was 16.5% and density was 1.26 g/cm^3.

Fluctuations in the field profile irregularities were high-frequency ones. This is definitely indicated by the length of the correlation relationship[1] of the ordinates of a given process: it does not exceed 0.3 m (Fig. 3). More over according to normalized autocorrelation function the oscillations in the amplitude of the longitudinal field profile contained a latent periodic component with a period approximately equal to 0.75 m.

Dispersion of the oscillations was also small (1.21 cm^2). It was concentrated in the frequency range of 0 ... 12 s^{-1}. When speed of the ploughing unit is 1.98 $m \cdot s^{-1}$, frequency is 0 – 24 s^{-1} or 0 – 4 Hz.

According to the correlation and spectral analysis of the Fig. 3 given above, it can be concluded that the relatively high frequency and small dispersion of variations in the unevenness of the longitudinal and vertical profile of the field cannot generate more or less significant oscillations of the traction resistance of the front-mounted and rear-mounted ploughs attached to ХТЗ-160 tractor.

The main changes in this parameter (i.e. traction resistance) will be formed and as a rule are formed by the internal structure of soil environment which is under influence of the tillage working tools.

[1]Abscissa axis of the first zero value of the normalized autocorrelation function ρ (Fig. 1)

The ploughs fort he units with ‘0 + 5’ and ‘ 2 + 4’ implement combination were adjusted on the same working depth of 25 cm.

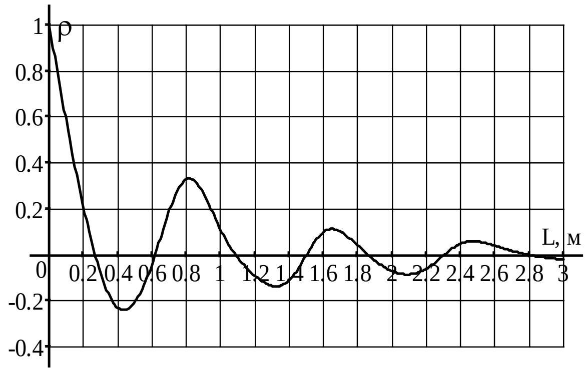

Figure 3. Normalized autocorrelation function (ρ) of field profile oscillations as a function of L path

Traction resistance of the plough unit with ‘0 + 5’ combination varied within the limits of 26.6 – 28.4 kN. Root mean square deviation of this parameter was ± 4.0 – 4.8 kN. As a result, the coefficient of traction resistance variation changed and made up 14.0-18.0%.This indicates the average variability of the process [Dospekhov B.A., 1985].

In comparison with ПЛН-5-35 implement, the total traction resistance of the front and rear-mounted ploughs of the unit with ‘2 + 4’ combination under approximately the same value of root mean square deviation (± 5 kN) made up 31.5 – 34.7 kN. Correlation time for these processes varied in this case in the 0.24 – 0.26 s range (Fig. 4).

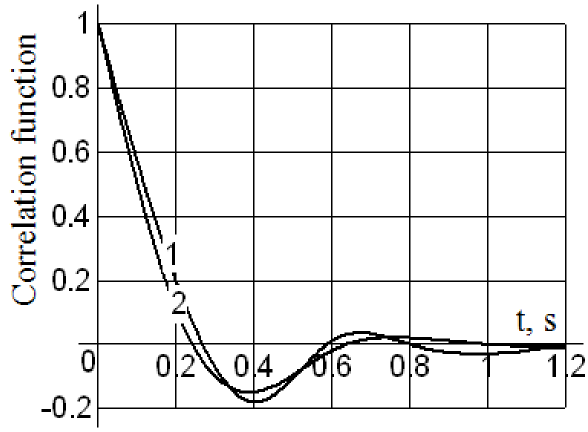

Figure 4. Normalized correlation functions of oscillations for traction resistance of the ploughs for the units with ‘0 + 5’ (curve 1) and ‘2 + 4’ (curve 2) implement combinations

Analysis of hands-on experience for those combinations showed that such duration of the correlation connection (as for time) characterizes the process as high-frequency one [Bulgakov V.M., Kravchuk V.I., Nadykto V.T., 2008; Nadykto V.T., 2017]. Spectrum of variances in the oscillations for plough traction resistance is relevant evidence of the fact. In the machine-tractor assemblies. It is concentrated in the frequency range of 0 – 25 s^{-1} or 0 – 4 Hz.

According to the results of measurements, the unit with a *Push-pull* (i.e. '2 + 4') combination had an actual working width of the implement 20.9% higher than the '0 + 5'ploughing unit had.

Operating speed of the ploughing combination with a single five-furrow plough was 1.5% higher due to the smaller working width and therefore less traction resistance of the mounted implement (Table 1).

Table 1

The results of experimental studies for ploughing combinations on the basis of XT3-16131 tractor

Ploughing combination	V_w 1), $m \cdot s^{-1}$	B_w 2), m	W_u 3), $ha \cdot h^{-1}$	h 4), cm	δ 5), %	P_{tr} 6), kN	G_h 7), $kg \cdot h^{-1}$	G_u 8), $kg \cdot ha^{-1}$
'0 + 5'	2,01	1,77	1,28	24,9±0,3	13,8	27,4	21,2	16,5
'2 + 4'	1,98	2,14	1,53	25,1±0,1	14,4	33,1	22,3	14,6

1) – working speed;
2) – working width;
3) – unit productivity per 1 hour;
4) – ploughing depth;
5) – wheelspin of tractor;
6) – tractive resistance of the plough;
7) – hourly fuel consumption;
8) – unit specific fuel consumption.

As a result, the productivity per 1 hour for the unit with '2 + 4' combination was 19.5% more than for the unit with a single rear-mounted five-row plough.

Since the tractive resistance of the ploughs with '2 + 4' implement combination is higher than that of the unit with '0 + 5' combination, it naturally had greater slippage of the tractor wheels (Table 1). In absolute terms it is by 0.6%, and in the relative terms it makes up by 4.3%.

At the same time due to higher productivity the specific fuel consumption of the *Push-pull* unit is 11.5% less. In our opinion this saving is possible due to more effective use of traction properties of the front axle of the tractor. The properties improvement is enabled because of front implement application. Its correct assembly causes loading of the front movers of the power equipment.

One of the main agrotechnical indicators of the ploughing unit work is uniformity of the depth of ploughing. According to the experimental data the mean square deviation of this parameter in both compared machines did not exceed the agrotechnical requirements (± 2 cm) and made up the following values: for the unit with '0 + 5' combination it was±1.98 cm and for the '2 + 4' implement combination it was ±1.52 cm.

According to results of a variance analysis difference between these mean square deviations is not random at a statistical significance level of 0.05. It is explained according to Fisher's F-criterion [Lurie, 1970] the null hypothesis as for the equality of the compared statistical estimates is not rejected.

It may be stated that with a confidence level of 95%, the'2 + 4' ploughing combination performs ploughing with a higher stability in the depth of tillage. One of the reasons for this result may be the fact that the front axle of the tractor XT3-160 performs less vertical vibrations when it moves in the furrow due to front-mounted plough application. As a result it positively affects the smoothness in operation of both the front and rear-mounted ploughs.

It should be emphasized that the normalized correlation functions and spectral densities of the oscillations of the working depth for compared ploughing combinations differ a little among themselves (Figure 5). For both versions of the implements, the length of the correlation is at least 21 m.

Moreover actual fluctuations in the depth of ploughing do not contain any latent periodic component. This result can be explained by the fact that the surface of the field was leveled before ploughing with the help of a disc harrow. Small variance of fluctuations in the field unevenness, which is only 1.24 cm^2, proves this.

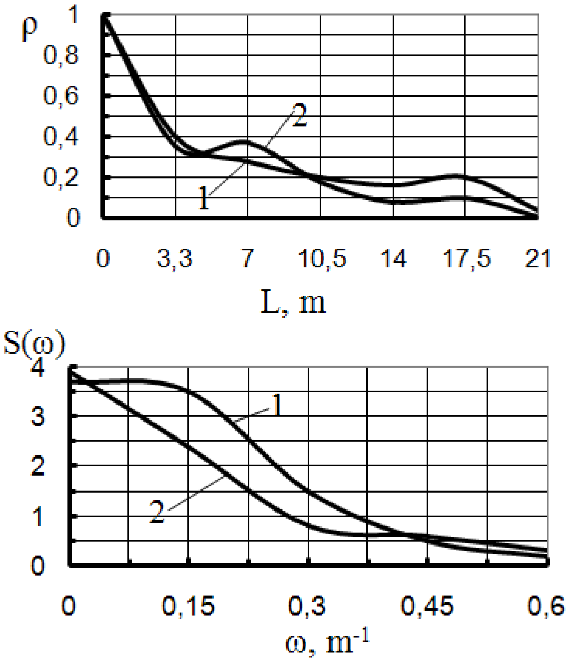

Figure 5. Normalized correlation functions (ρ) and spectral density [S (ω)] for oscillation of ploughing depth for the units with ‘0 + 5’ (curve 1) and ‘2 + 4’ (curve 2) implement combinations

Moreover during the operational movement the tractor wheels have a certain slippage. And since this process is accompanied by the cutting of the soil by the soil-hooks of the movers, an additional alignment of the power unit path takes place. The amplitude of its vertical oscillations decreases in this case. This causes decrease in vertical oscillations of the ploughs which are mounted on a tractor. The final consequence of this is increase of ploughing depth stability for the *Push-pull* system.

CONCLUSIONS

The advantages of front mounted agricultural machines make it possible to create a basis for highly efficient *Push-pull* implement combinations.

Push-pull ploughing unit with ХТЗ-16131 tractor, two-furrow front and four-furrow rear ploughs (‘2+4’) in comparison with the combination of the same power unit and a rear five-furrow tillage implement (‘0+5’) has a 19.5% increase in productivity and a lower (by 11.5%) fuel consumption.

The use of the ‘2+4’ ploughing unit provides higher stability of plough motion while tilling.

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FOUNDATION OF OPERATING PRACTICES OF SEED MEAL MOISTURE AND HEAT TREATMENT ON OIL EXTRACTION FROM CASTOR BEANS

Volodymyr Didur, Doctor of Engineering
Andrey Chebanov, PhD of Engineering
Volodymyr Didur, PhD of Engineering
Anatoliy Aseev, Engineer

Tavria State Agrotechnological University

Moisture and heat treatment of the castor beans with intensive mixing and bringing its humidity and temperature to optimum values for a given period of time causes a change in a number of physical and chemical properties of the castor-oil seed meal and oil contained in it. This promotes a better oil extraction effect. Moist and heat treatment is one of the most important technological operations in the castor bean preparation for the oil extraction through pressing and has a decisive influence on the quantity and quality of the final products: oil, oilcake or solvent cake. To substantiate the necessary operating practices for moisture and heat treatment of the castor-oil seed meal, an experimental complex was developed to extract oil from oil-bearing raw materials and the experiment procedure was determined.

Experimental researches have established several operating practices of castor-oil seed meal roasting. 1) At steam pressure in a steam generator of 3 kg / cm^2, the seed meal moistening time (at an initial humidity of 5.8%) to a moisture content of 10 ... 13.5% is 30 ... 55 seconds, and the drying time to a humidity of 6 ... 9% is 75 ... 150 minutes; 2) at a steam pressure of 4 kg / cm^2, the seed meal moistening time (at an initial humidity of 5.8%) to a moisture content of 10 ... 13.5% is 35 ... 60 seconds, and the drying time to a humidity of 6 ... 9% is 75 ... 150 minutes; 3) at a steam pressure of 5 kg / cm^2, the seed meal moistening time (at an initial humidity of 5.8%) to a humidity of 10 ... 13.5% is 45 ... 80 seconds, and the drying time to a humidity of 6 ... 9% is 55 ... 100 minutes. As a result of experimental studies, calibration curves have been obtained, which determine the time for the technological operations of seed meal moisture-heat treatment to obtain a target value of its moisture content.

Keywords: castor beans, ground seeds, seed meal, roasting, steam generator, steam pressure, moistening period, drying period, seed meal moisture, seed meal bed height.

INTRODUCTION

The oil in the castor-oil seed meal is distributed in the form of thin films on the surface of particles of ground castor-oil beans (ground seeds) and is held by the forces of intermolecular interaction. Their value is much higher than the pressure gathered by modern presses used for its wringing. Therefore, by oil extraction (pressing) from an unprepared seed meal, a small amount of the final product is obtained. The task of seed meal preparing (moisture and heat treatment or the roasting process) before pressing is to decrease the forces that hold the oil in the seed meal. This is obtained by seed meal moistening. But the moistened seed meal becomes very plastic, and therefore, when pressed, oil is poorly separated from it. To impart it certain elastic properties the moisture is removed from the seed meal, this is obtained by drying [Maslikov V.A., 1974; Goldovsky A.M., 1958]. However, the moistening and drying indices of the castor-oil seed meal according to different sources vary greatly [Didur V.V., Chebanov A.B., Aseev A.A., Shariy A.V., 2016; Didur V.A., 2005]. This makes it difficult to select valid operating practices when oil is squeezed out on the experimental line.

In the industry, there are two types of seed meal roasting: wet and dry [Kopeykovskii V.M., Danilchenko S.I., Garbuzova G.I., 1982; Beloborodov V.V., 1974; Koshevoi E.P., 2001]. The first type roasting proceeds in two

Contact info: Melitopol, Ukraine, didurva@gmail.com

stages. At the first stage, the seed meal is moistened and heated through adding water, followed by steaming and bringing the moisture content and temperature of the oil-bearing material to optimum values, which are determined by the individual properties of the seed meal. The second stage is drying the moistened seed meal with the optimal structure producing and bringing its humidity and temperature to the values proper for pressing.

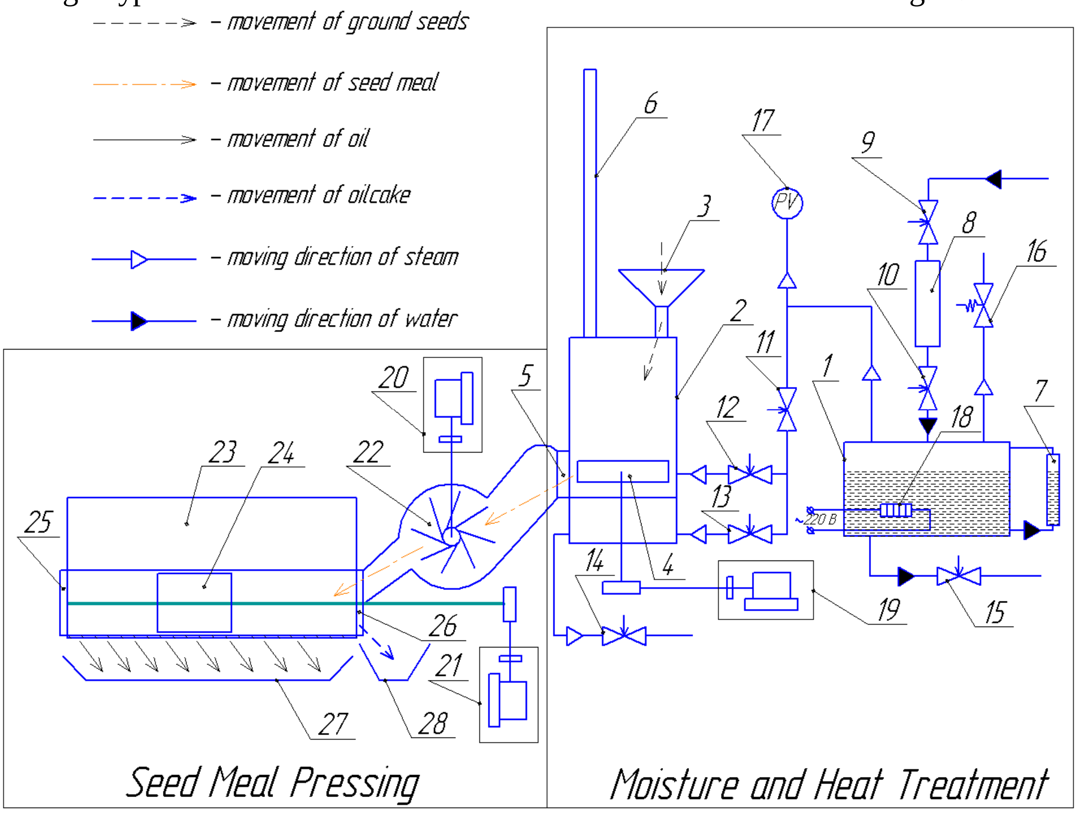
Roasting of the second type is drying and heating the seed meal to certain values without preheating and prior moistening. Thus, the roasting practically begins at once from the second stage. It consists in the exclusion of moisture contained in the material itself, and in bringing the temperature and humidity of the seed meal to the optimum values for pressing.

Roasting of the second type can be recommended in cases where undesired chemical and biochemical processes occur during the seed meal moistening. In addition, this roasting type is recommended when processing raw materials with initial moisture content higher or equal to the humidity limit, which is set for the first roasting stage final.

The first roasting type is more efficient and provides not only the optimum characteristics of the material before its pressing, but also the chemical changes necessary for producing oil, oilcake and solvent cake of the desired quality [Kopeykovskii V.M., 1982]. This is the determining factor in making choice of the roasting method in further studies. The purpose of this work is to found the operating practices of castor-oil seed meal roasting in the roaster of the experimental oil extraction complex.

MATERIALS AND METHODS

The technological process investigations of castor-oil seed meal roasting and the rational values determination of its parameters are performed on an experimental plant, which technological scheme is shown in Fig. 1. The overall view is shown in Fig. 2.



1 - steam generator; 2 - a roaster; 3 - the feeding box; 4 - a stirrer; 5 - the discharge opening; 6 - a steam pipe; 7 - a gauge glass of the steam generator; 8 - an additional water tank; 9-15 - through control valve; 16 - a safety valve; 17 - pressure sensor; 18 - a heating element; 19-21 - an electric motor with a reducer; 22 - beater; 23 - a press; 24 - a press piston; 25-26 - a press valve; 27 - oil collection reservoir; 28 - container for oilcake collection.

Figure 1. Technological scheme of the experimental complex for oil extraction from oil-bearing raw material

Figure 2. Overall view of the experimental complex for oil extraction from oil-bearing raw material

Roasting (moistening and drying) of the castor-oil seed meal occurs in the roaster 2. According to the manufacturing method, the water is fed in the steam generator 1 through an open through control valve 9, an additional water tank 8 and a through control valve 10. The water level monitoring is performed using a gauge glass 7.

After the required water level in the steam generator 1 is obtained, the valves 10 and 9 are closed. The water is heated by three heating elements 18, which are located in the tank of the steam generator. The pressure in the steam generator 1 is controlled by a pressure-gauge 17. The emergency pressure is controlled by a safety valve 16.

The ground seeds are fed into the roaster 2 through the feeding box 3. The necessary ground seed level is provided by means of a measuring scale inserted into the feeding box. Stirring during the roasting process is performed by a stirrer 4 driven by an electric motor with a reducer 19. The steam is removed during the roasting process through a steam pipe 6. The seed meal moistening is carried out by the steam, which is fed to the roaster tank 2 through the open valves 11 and 12. The valve 13 is thus closed. Moreover, the valve 12 is fully open, and the valve 11 is open in such a position that the vapor pressure, controlled by the pressure sensor 17, remains unchanged. Seed meal drying is carried out by the indirect heating vapour fed to the lower part of the roaster through the valves 11, 13 and 14. To obtain this, the valve 12 is closed and the valves 13 and 14 are opened completely. The valve 11 position does not change for the preset pressure value. The seed meal roasting ends with the material unloading through the discharge opening 5. The through valve 15 is necessary for water drain from the steam generator.

For experimental investigation conducting the castor-oil bean variety *Khortitskaya 7* was used. Refinement of castor-oil beans to ground seeds was carried out by a special roller press. The gap between the grinding rolls was set taking into account the physical and mechanical characteristics of the beans (length, width and thickness). Determination of these characteristics was carried out using the methods recommended in accordance with [DIDUR V.A., 2004].Before the experiments, the initial ground seed moisture was determined according to [GOST 5947-68, 1968]. In this case, the mass of water in the test material (g_m) was determined as follows:

$$g_m = g - g_{d.sub}\,, \qquad (1)$$

where g is the total mass of wet material, kg;

$g_{d.sub}$ is the weight of dry substance, kg.

The moisture content of the test material with respect to the total mass (in %) was determined as follows:

$$w = \frac{g_m}{g_{d.sub}} \cdot 100\,. \qquad (2)$$

When preparing the ground seeds for roasting in the roaster, the determining parameters are: the heating steam pressure $p_{h.s}$, the seed meal bed height *H*, the initial seed meal moisture content W_{in}, the finite seed meal moisture separately for the moistening periods $W_{f.m}$ and drying $W_{f.d}$.. The roaster of the experimental plant has one tank, the number of revolutions of the roaster stirrer 4 does not change and is 32.5 rpm.

As already noted in various sources, the values of the finite moisture content during moistening and drying of the castor-oil seed meal are different, therefore, in order to carry out further studies on oil pressing, the maximum values with the obligatory examination of several average values are accepted. That is, the finite castor-oil seed meal moisture content for the moistening period will be controlled to the level $W_{f.d}$=13,5%, the finite castor-oil seed meal moisture content for the drying period will be controlled to the level $W_{f.d}$=6%. The heating steam pressure during the studies is assumed to be $p_{h.s}$ = 3 kg / cm^2, 4 kg / cm^2 and 5 kg / cm^2. The ground seed bed height in the roaster can vary from H = 0 mm to H = 240 mm. Carrying out preliminary experiments allowed determining the parameters for loading the ground seeds into a roaster. So, in order to provide the necessary amount of castor-oil seed meal, which is fed to the castor-oil extracting press, a sufficient ground seed bed height in the roaster is 160 mm.

In order to obtain a constant amount of steam, it is necessary to calibrate the through control valve 11 for a different pressure. To do this, the steam generator is filled with water, all the heating elements 18 are switched on and steam pressure $p_{h.s}$ = 5 kg / cm$_2$ is produced. The valves 13 and 14 are opened completely, and the valve 11 is opened to such a position that the steam pressure, which is controlled by the pressure gauge 17, does not change. When this position of the valve is fixed, a mark is made. The same marks are made for pressure values $p_{h.s}$ = 4 kg / cm$_2$ and $p_{h.s}$ = 3 kg / cm$_2$.

For the moistening period of the seed meal, it is also necessary to determine the capacity of the steam generator (kg / sec). To do this, a container with water was taken. It was weighed. The hose beyond valve 14 was installed into this container with water and compacted. In the steam generator, a vapor pressure $p_{h.s}$ = 5 kg / cm$_2$ was generated. The valves 13 and 14 were fully open, and valve 11 was open at the required mark. At that, the time was controlled, which made up 30 seconds. After 30 seconds, valves 11, 13 and 14 were closed, and the container with water was weighed again.

The productivity of the steam generator was determined using:

$$Q_{sg} = \frac{m_c - m_{s.c}}{t}\,, \qquad (3)$$

where m_c is the mass of the container with water before the research, gr;

$m_{c.s}$ is the mass of the container with water and steam after the research, gr;

t is time while the studies were conducted, sec.

The same experiments were carried out for pressure values $p_{h.s}$ = 4 kg / cm$_2$ and $p_{h.s}$ = 3 kg / cm^2.

To ensure the ground seed bed height which is fed into the roaster, it is necessary to calibrate the tank of the roaster. To do this, a depth of the roaster tank was measured with a measuring scale through the feeding box 3 and the value was recorded. Then the ground seeds were fed into the roaster tank. Periodically, the electric motor with a reducer 19 was turned on and ground seeds were mixed with a stirrer 4. The ground seeds were fed so that the measured value on the measuring scale was reduced by 160 mm and the mark was made on the scale at the upper border level of the feeding box.

In order to determine the amount of steam, to moisten the castor oil ground seeds to the finite moisture content (13.5%), it is necessary to determine the ground seed weight for the appropriate bed height. To do this, weighed ground seeds were fed into the roaster. At the same time, the bed height of the ground seeds being fed was controlled. For a bed height of 160 mm, the mass was fixed.

The amount of steam necessary to moisten the ground seeds to the finite moisture content was determined by means of formula

$$\Delta g_m = g_1 \frac{w_2 - w_1}{100 - w_1}, \qquad (4)$$

where g_1 is the castor oil ground seed mass with initial humidity w_1, kg;

w_1 is the initial moisture of the ground seeds, %;

w_2 is the finite moisture of the ground seeds,%.

The time required to moisten the ground seeds to the finite moisture w_2 at a given pressure $p_{h.s}$ was determined using:

$$T = \frac{\Delta g_m}{Q_{s.g}}, \qquad (5)$$

To carry out the research on the experimental plant (Figure 1), the following equipment and materials should be provided:

- an oven;
- scales graduated to 0.001 g;
- aluminium weighing bottles for samples with the test material;
- the material under examination (castor-oil seed meal).

The algorithm for carrying out the experiments is as follows:

1. Weigh each empty weighing bottle on the scales graduated to 0.001 g.
2. Generate a steam pressure in the steam generator 1 equal to $p_{h.s}$ = 5 kg / cm_2, which is controlled by a manometer 17. If there is a high steam pressure, it should be released. To do this, the valves 11, 13 and 14 are opened.
3. Feed the weighed ground seeds into the roaster 2 to a bed height of 160 mm. Calculate from the formulas (4) and (5) the amount of steam and the time required to moisten the ground seeds to the finite moisture w_2.
4. Switch on the electric motor with a reducer 19, which rotates the stirrer 4 of the roaster 2.
5. For the moistening period. Open fully the valve 12 and open the valve 11 at the corresponding mark (the valve 13 is closed). The time, calculated from formula (5) to moisten the ground seeds to the finite moisture, must be proportionally divided into four periods. After each period, open the throttle of the discharge opening 5 and take a ground seed sample in the weighing bottle.
6. For the drying period. Open fully the valve 13, and close the valve 12. Do not change the position of the valve 11. Carry out drying until the water level in the steam generator 1 controlled by the measuring glass 7 reaches the lower level. This time interval is divided into several periods. After each period, open the throttle of the discharge opening 5 and take a ground seed sample in the weighing bottle.
7. Weigh each weighing bottle on a scales graduated to 0.001 g.
8. Determine the moisture content of the samples by drying them to perfectly dry mass by the procedure mentioned in [GOST 5947-68, 1968]. At that, the mass of water in the test material and the moisture content of the material with reference to the total mass are calculated from formulas (1) and (2).
9. It is necessary to take samples of the ground seeds throughout the bed height (in order to determine how the ground seeds are steamed throughout the bed height). To do this, divide the bed height by the graduated scale into 4 segments. Insert the scale into the feeding box 3. Open the throttle of the discharge opening 5 and unload the ground seeds to the

appropriate mark. At each mark, take a ground seed sample in the weighing bottle.

10. Repeat experiments 1-9 with steam pressure in the steam generator 1 $p_{h.s}$ = 4 kg / cm_2 and $p_{h.s}$ = 3 kg / cm_2.

RESULTS AND DISCUSSION

The seed meal moisture curves from moistening time at a steam pressure of 3 kg / cm_2, 4 kg / cm_2 are shown in Fig. 3. The dependence analysis results that with an increase in the heating steam pressure, the moistening time increases. Thus, for example, at a steam pressure of 3 kg / cm2, the time necessary for seed meal moistening (at an initial moisture content of 5.8%) to a moisture content of 13.5% is 55 seconds. At a steam pressure of 5 kg / cm_2, the same seed meal moisture is obtained in 75 seconds. The explanation of this is that disparity of specific weight of steam and liquid decreases with pressure increase.

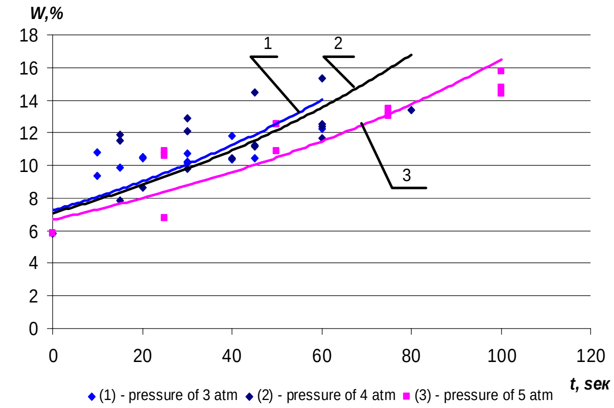


Figure 3. Dependence of the seed meal moisture content on the moistening time

The seed meal moisture curves at the bed height in the roaster tank immediately after moistening at steam pressure of 3 kg / cm_2, 4 kg / cm_2 and 5 kg / cm_2 are shown in Fig. 4. With an increase in the bed height, the seed meal moisture decreases, which is a consequence of the design features of the roaster (steam is brought about to the roaster bottom).

The seed meal moisture curves from the drying time are shown in Fig. 5. As dependencies indicate, with drying time increase, the seed meal moisture decreases. This process is influenced by the steam pressure. Thus, at the initial moisture after the seed meal moistening process at 13.5% and the steam pressure of 5 kg / cm_2, the seed meal moisture content of 6% is obtained after 100 minutes. At a steam pressure of 3 kg / cm_2, the same seed meal moisture is obtained after 150 minutes only, which accounts for a steam temperature decrease and, correspondingly, by drying rate increase [Maslikov V.A., 1974; Maslikov V.A., 1965].

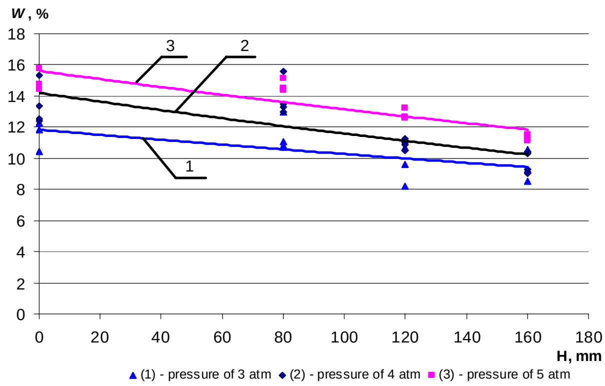


Figure 4. Dependence of the seed meal moisture on the bed height in roaster tank after moistening

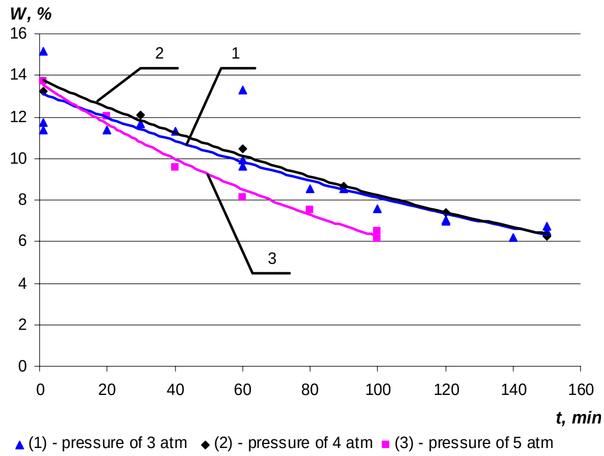


Figure 5. Dependence of the seed meal moisture content on the drying time

The drying process is due to thermal diffusion, which causes moisture transfer in the direction of heat, that is, from the more heated part to the colder one. The moisture transfer occurs as a result of moisture differential in the different seed meal layers: from the layers with more moisture the moisture moves into layers with less moisture. The moisture differential is created by the temperature difference. The more the temperature difference is, the more intensive drying takes place. This is confirmed by the curves of the seed meal moisture content throughout the bed height in the roaster tank after drying at a steam pressure of 3 kg / cm_2, 4 kg / cm_2 and 5 kg / cm_2 in Fig. 6. If, after moistening (Fig. 4), for example, at a pressure of 5 kg / cm_2, the moisture content throughout the bed height varied from 15.5% in the lower part of the roaster to 12% at the top, then after drying (Figure 6), the moisture content varied from 6.2 to 6.3%. That is, it can be asserted that after drying there is a uniform steaming of the seed meal layers at any roaster height.

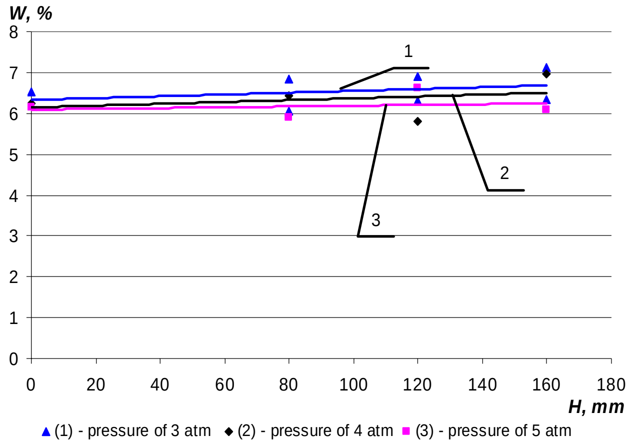


Figure 6. Dependence of the seed meal moisture content change on the layer in the roaster tank after drying

CONCLUSIONS

Experimental researches established operating practices of castor-oil seed meal roasting:

- at a steam pressure of 3 kg / cm_2, the time of seed meal moistening (at an initial moisture content of 5.8%) to a moisture content of 10 ... 13.5% is 30 ... 55 seconds; drying time to moisture content of 6 ... 9% is 75 ... 150 minutes;

- at a steam pressure of 4 kg / cm_2, the time of seed meal moistening (at an initial moisture content of 5.8%) to a moisture content of 10 ... 13.5% is 35 ... 60 seconds; drying time to moisture content of 6 ... 9% is 75 ... 150 minutes;

- at a steam pressure of 5 kg / cm_2, the time of seed meal moistening (at an initial moisture content of 5.8%) to a moisture content of 10 ... 13.5% is 45 ... 80 seconds; drying time to moisture content of 6 ...9% is 55 ... 100 minutes/

The presented curves serve as calibration curves when the oil extraction in the reamed channel.

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MECHANICAL-TECHNOLOGICAL FUNDAMENTALS OF THE FRONT-WEIGHTED HAULM GATHERER ON THE WHEELED TRACTOR

Volodymyr Bulgakov[1]*, Doctor of Engineering, academician*
Evgeniy Ignatiev[2]*, Engineer*
Vladimir Kročko[3]*, Doctor of Engineering*
Pavol Findura[3]*, Doctor of Engineering*

[1]National University of Life and Environmental Sciences of Ukraine
[2]Tavria State Agrotechnological University
[3]Slovak University of Agriculture in Nitra

Sugar beet harvesting is a complex and energy-intensive technological process in the production of this technical crop. At the present time, the process of harvesting sugar beet haulms is carried out on the root and is performed in two steps: firstly a continuous uncopied cut of the main area of green mass and subsequent individual post-cleaning of the root crop heads from the haulm remains. The increased working harvesting rate causes intensive fluctuations of the cutoff apparatus in the longitudinally vertical section that doesn't only reduce the quality of root crops cutting but also causes significant losses of the haulms. The use of haulm gatherers as independent harvesting modules allows aggregating them with various types of row tractors that makes it necessary to determine the compliance of the definite haulm gatherer with the traction and energy characteristics of tractors which will ensure high efficiency of using the proposed machine and tractor units. The purpose of this study is to increase the efficiency of using a front mounted haulm gatherer on the wheeled tractor based on the development of thebasic regulations of the theory of its aggregation and determining the influence of its kinematic and design characteristics on the quality of a continuous cut of the haulm with oscillations of the cutting device in the longitudinal-vertical plane. While making research the methods of the theory of mathematical modeling of agricultural machines and machine aggregates, the theory of the tractor, the foundations of machine use in plant growing, and the compilation of the programs and numerous calculations on the PC were used. Conducted investigations made it possible to develop mathematical models of the movement of a haulm gatherer determining the optimum shear height, and also to justify and select the optimal parameters of machine-tractor aggregates which are made up of a tractor and a front unloaded haulm gatherer. The developed mechanical and technological fundamentals of aggregation make it possible to determine the optimal design and kinematic parameters both of the botting harvester and the aggregates according to the criteria of productivity and energy intensity.

Keywords: sugar beet, rotary cutter, aggregation, tractor, math model, characteristics/specifications, fluctuations, differential equations.

INTRODUCTION

Modern technologies for harvesting sugar beet haulms suggest firstly a continuous, uncopied cut of the main mass of green mass and subsequent individual finishing of the heads of root crops from the remains of the haulms, Bulgakov (2011). At the same time, the first technological operation to cut the main mass of the green foliage assumes the main harvesting of its harvest (continuous uncopied cut, collection of sloping mass and unloading), its transportation for further use for animal feed, as fertilizer or raw material for biogas production. Thus, it is important to establish optimal characteristics of the continuous main cut so that the heads of the root crops are not damaged and it is not too high since in this case the post-cleaning of the heads is complicated by the existing additional cleaning organs of the haulm gatherers. The use of haulm gatherers as independent harvesting modules allows to aggregate them with various types of row tractors. This raises the need to determine the

Contact info: Melitopol, Ukraine, mvz@tsatu.edu.ua

compliance of a haulm gatherer with the traction-energy parameters of the aggregating tractors which will ensure high efficiency of the proposed harvesting machine and tractor units. However, the high efficiency of the harvesting of the agricultural machine and tractor unit is achieved due to the fact that there will be a correct correlation between its technical parameters, operation modes and external production conditions. Therefore, the issues of effective use of haulm gatherers are urgent and require an appropriate scientific substantiation.

ANALYSIS OF RECENT RESEARCH

Questions of the theoretical study of the aggregation of agricultural machines connected with the construction of computational mathematical models for the functioning of various self-propelled and trailed machine aggregates are presented in detail in the scientific works by Vasilenko (1980, 1996). At the same time, the work written by Bulgakov (1980, 2007) is devoted to the construction of computational mathematical models of trailed agricultural machines including sugar beet and flax harvesting machines.

The theory of aggregation of trailed and rear-mounted agricultural machines is widely represented in the fundamental works of Kutkov (2004) and Nadykto (2003).

According to the research results by Boris (2009) and Bulgakov (2011) it is established that there is a definite linear relationship between the height of the placement of the heads of root crops above the soil surface and the dimensional characteristics of the most root crops. However, studies that would affect the analytical determination of the total weight of the cut-off haulage during its continuous cutting with a rotary cutting apparatus have not been carried out sufficiently yet.

Fundamental questions of forecasting the degree of increase in the productivity of sugar beet harvesting machines depending on the specific investment were examined by Pogorely (1984). However, the choice of the optimal parameters of front-mounted bot-harrowing machines according to the performance criteria of the aggregating tractor is not considered here.

Methods for obtaining performance characteristics of various machine-tractor aggregates made up of aggregating tractors and mounted machines and tools are widely represented in the works by Fere (1978) and Pastukhov (2001).

Therefore, on the basis of all the above-stated it follows that the efficiency of the use of aggregated beet harvesters must first of all be evaluated as part of the aggregating tractor and justify this efficiency with the help of quantitative criteria that would accurately display their operational properties and technical excellence. Among these criteria there should be attributed, first of all, the performance of such aggregate, minimum operating costs, specific performance per 1 kW of power of the unit tractor and other performance indicators.

RESEARCH METHODOLOGY.

While conducting research the methods of the theory of mathematical modeling of agricultural machines and machine aggregates, the theory of the tractor, the foundations of machine use in plant growing, and the compilation of programs and numerical calculations on a PC were used.

The purpose of the study is to increase the efficiency of using a front mounted vehicle on the wheeled tractor based on the development of the main provisions of the theory of its aggregation and determining the influence of its kinematic and design parameters on the quality of a continuous cut of the haulm top with oscillations of the cutting device in the longitudinal-vertical plane.

RESULTS AND DISCUSSION.

The use of haulm gatherers as independent technological modules in the harvesting of sugar beets allows to aggregate them with various types of wheeled tractors equipped for this purpose with front attachments and front power take-off shafts. The aggregate tractor must be tilled, i.e. it is equipped with narrow tires set to the corresponding track width, i.e. corresponding rowing of sugar beet root crops. Besides, the haulm gatherers were viewed frontally mounted on an aggregating power tool (tractor).

To ensure these conditions, the design of the haulm gatherers was developed (Ignatiev

(2016)) which carries out a continuous, uncopied cut of the bulk of the tops, the loading of the mown mass in a nearby vehicle and which is front mounted on a wheeled tractor (Figure 1). This botting harvester can be manufactured in various layout designs, i.e. various ranks from two-row to six-row variants.

To develop a new theory of effective aggregation of a front-mounted machine mounted on the wheeled tractor using the well-known dependencies to determine the productivity of the machine-tractor unit the

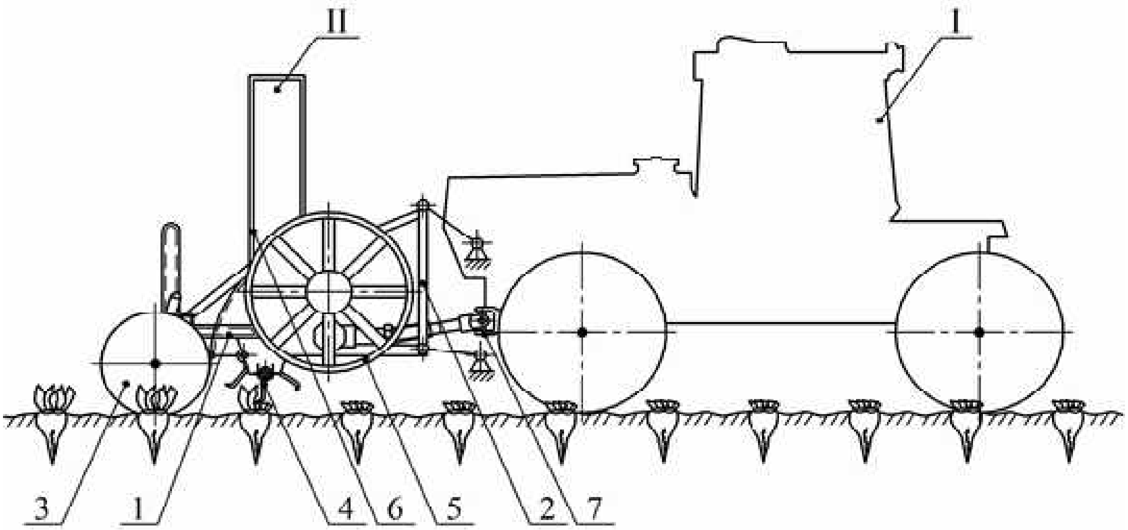

Figure 1. Aggregate for harvesting sugar beet haulms:
I - wheel integral tractor-tractor; II - front mounted hoeing machine:
1 - frame; 2 - hinged device; 3 - copying wheel; 4 - rotary cutter apparatus;
5 - transporting working body; 6 - loading device; 7 – drive.

$$W = 0{,}1B\left\{ \frac{3600\cdot\xi\cdot N_e\eta_t\eta_v\left[1+\frac{1}{b}\ln\frac{\left[(mg\cdot\psi+kB)\cdot(mg\cdot\lambda)^{-1}\right]-\varphi}{\alpha}\right]}{(kB+mg\psi)\eta_v+10N_pB\cdot H\eta_t\left[1+\frac{1}{b}\ln\frac{\left[(mg\cdot\psi+kB)\cdot(mg\cdot\lambda)^{-1}\right]-\varphi}{\alpha}\right]}\right\}, \quad (1)$$

where N_e - rated, effective engine power, kW;

ξ - engine load factor;

N_p - the specific energy consumption for the process of harvesting the tops of sugar beet, kW·s· kg^{-1};

H - yield of sugar beet tops, c / ha;

η_t - the efficiency of the transmission of the wheel assembly tractor;

η_v - efficiency of the front power take-off shaft of the tractor;

α - angle of rise, rad .;

m- the mass of the wheeled tractor, kg;

g - acceleration of gravity, m · (s^2) $^{-1}$;

k- specific resistance of the front-mounted haulm gatherer, H · м$^{-1}$;

ψ - drag coefficient to the movement of the wheel assembly tractor;

φ - utilization factor of the coupling weight;

a, b - constant coefficients that depend on the type of wheeled tractor and agrophone on which the sugar beet tops are harvested;

λ - traction factor of the tractor;

B- working width of the gripper front mounted on the wheeled tractor, m.

following expression was obtained (1).

The resulting expression (1) is a mathematical model of the aggregation of a front mounted haulm gatherer on a wheeled tractor using which it is possible to determine the performance of the machine-tractor unit depending on the initial parameters of a particular tractor and haulm gatherers of various ranks and layout.

The technical characteristics that concern universal-tilled and integral wheeled tractors with which it is possible to aggregate a front-mounted haulm gatherer are given according to the data of Pastukhov (2001) in Table 1.

Table 1.Technical characteristics of tractors

Tractor draw bar category, purpose	mg, kg	N_e, kW	φ_m	a	b
0,9 universal, wheeled	3000	36,8	0,6	0,75	8,81
1,4 universal, wheeled	3810	58,9	0,6	0,75	8,81
3 intergratedrow-crop, wheeled	8200	117,7	0,65	0,753	9,52

Based on the analysis of numerical calculations carried out on a PC in the Mathcad mathematical model (1), it can be argued that wheeled tractors of class 0.9 and 1.4 will provide sufficient and stable performance only when three- or four-row haulm gatherers are assembled, and the use of a six-row machines is possible only at low values of resistivity up to 2100 ... 2300 N · m-1. At the same time, a class 3 wheeled tractor will provide a fairly high productivity of 3,3 ... 3,5 ha · h-1 with the addition of a six-row hitch at any resistivity values, and thanks to the power reserve it's possible to use a rear-mounted head cleaner or a haulm gatherer.

To solve the next important issue which concerns the choice of the optimal height of the main continuous cut of the haulms the value of which will directly depend on the height of the protruding heads of the sugar beet root crops above the soil surface, which is a random quantity, we will develop a mathematical apparatus that will predict the loss of the sugar-containing mass.

Let us consider the loss of the sugar content and the remains of the foliage which are determined by the distance from the established cut height h to the top of the head of the root crop bt and the base of the green eye zone bh (Fig. 2).

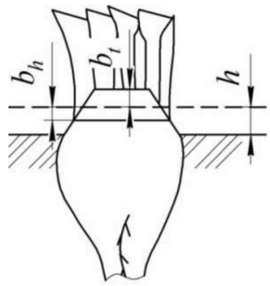

Figure 2. Scheme of root cropping

Setting these parameters and using the geometric calculations let's determine the volume of the cut part of the crop root and the remains of the foliage taking into account their density, and it is possible to determine the mass characteristics of the unknown quantities for root crops of a given height interval (Boris (2009)):

$$M_i = F\left(h_i;b_i\right)\cdot P\left(h_i;h_{i+1}\right)\cdot N_i, \quad (2)$$

where: F - loss of the sugar content or the remains of the foliage, for the root crop;

$$M = \sum_{i=a}^{b}\left[N_i \cdot F\left(\frac{h_i + h_{i+1}}{2};b_i\right)\cdot\left(\frac{h_{i+1}-h_i}{3m}\sum_{j=0}^{m} c_j \cdot f(h_i)\right)\right], \quad (3)$$

where b_i - cutting height respectively of the tops or heads of the root crop;
F - loss mass of the sugar-containing mass or the remains of the foliage;
H - height of the unpaired cut of the haulms above the soil surface;
M - number of intervals: m = 2U; U = 1, 2, 3, 4, ...;
C_j - coefficient for the values of the integrand at the corresponding points, cj = 1, 2, 3, 4, 2, 4, ..., 2, 4, 1 ...

P - probability of occurrence of the given interval of heights of heads of sugar beet;

N_i - number of root crops of a given interval per unit area.

The determination of the probability of the appearance of root crops of a given interval of protuberant heights is calculated by numerical integration using the Simpson formula. Adding the general remains of the tops and loss of the sugar content for all intervals of protuberance heights we obtain the total remains of the tops and loss of the sugar content per unit area (3)

Using the above dependence it's possible to develop the algorithm and program for computing on a PC. Applying this mathematical apparatus the loss of the sugar content and the remains of the foliage is calculated as a function of the height of the uncopied cut (Fig. 3).

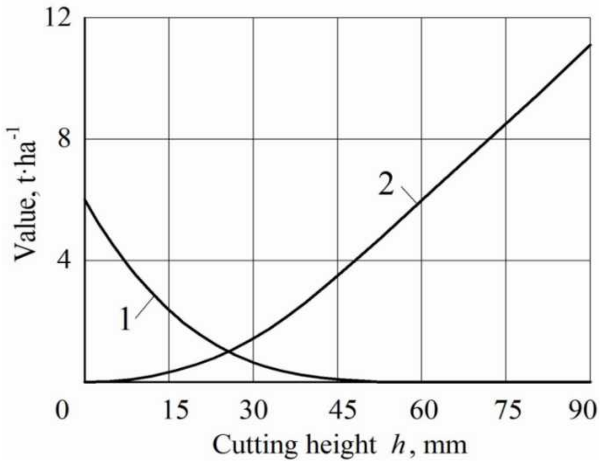

Figure 3. Dependence for determining the rational height of the main continuous cut at mathematical expectation m = 40 mm and mean square deviation σ = 10 mm: 1 - loss of sugar content, t · ha-1; 2 - mass of the remains of the tops, t · ha-1

Therefore, there is a reason to use the obtained mathematical dependence for forecasting losses of sugar-containing mass and haulm residues for different varieties of sugar beet and various technologies for its cultivation. Based on the obtained dependencies which are shown in Fig. 3 it is possible to determine the height of a continuous uncopied cut with the predicted losses of the sugar-containing mass and the remains of the foliage.

To determine the effect of the structural and kinematic parameters of the bot-harvesting machine, which is front-mounted on the wheel integral tractor, on the magnitude of the amplitude of oscillations in the longitudinal-vertical plane of the cutoff apparatus, it is necessary to construct its mathematical model.

To do this, let us analyze analytically the movement of the haulm gatherer only in the longitudinal-vertical plane, that is, we'll construct a mathematical model of the oscillation of the haulm gatherer when moving along the unevenness of the soil surface in only one plane. Based on Vasilenko (1996), we will first of all compile an equivalent scheme for the movement of the front-mounted machine mounted on the aggregating wheel integral tractor in the longitudinally vertical plane (Fig. 4).

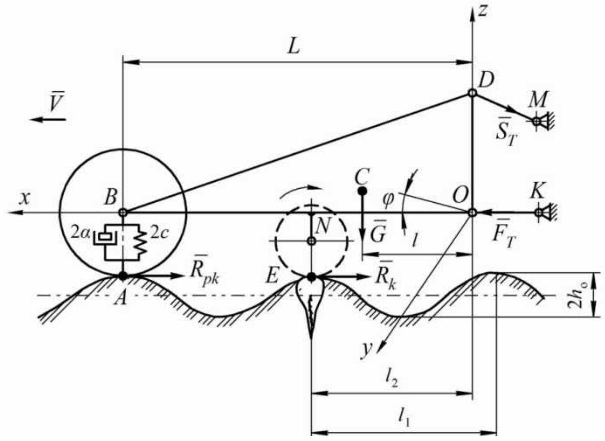

Fig. 4. Equivalent scheme of the front mounted haulm gatherer
on the aggregating integrated tractor

Based on this equivalent scheme and determining the potential forces and forces of viscous resistance (Butenin (1985), the following differential equation is obtained:

$$z = e^{-\frac{\alpha}{m}t}\left(-\frac{\frac{\alpha}{m}(N+R)+\frac{2\pi V}{l_1}M}{\sqrt{\frac{\alpha^2}{m^2}-\frac{2c}{m}}}\cdot\sin\sqrt{\frac{\alpha^2}{m^2}-\frac{2c}{m}}\cdot t - (N+R)\cdot\cos\sqrt{\frac{\alpha^2}{m^2}-\frac{2c}{m}}\cdot t\right)+M\cdot\sin\frac{2\pi V}{l_1}t+ N\cdot\cos\frac{2\pi V}{l_1}t+R, \quad (4)$$

where: α - coefficient of damping of the copying wheels, H · s · m^{-1};

m - mass of copying wheels, kg;

t - time, c;

c - coefficient of rigidity of pneumatic tires of the wheels of the copying system, N · m^{-1};

l_1 - step of unevenness of soil surface, m;

V - forward speed of the movement of the botting harvester, m · s^{-1};

R- the coefficient that equals $R = h_o$;

M, N - coefficients which are determined from expressions (6), (7) respectively.

Expression (4) defines the law of translational vertical oscillations of the center of mass of the copying wheels (point B) during the movement of the haulm gatherer along the unevenness of the soil surface given by the analytical expression in the form (Morozov (1969)):

$$h = h_o\left(1 - \cos\frac{2\pi x}{l_1}\right), \qquad (5)$$

where: *h*- the ordinate of the height of the unevenness of the soil surface, m;

h_o - half the height of the unevenness of the soil surface, m;

$x = Vt$ - current coordinate, m.

Coefficients *M* and *N* are determined after use of Cramer's rule:

$$M = \frac{\Delta_M}{\Delta} = -\frac{16\pi^3\alpha V^3 h_o}{ml_1^3\left[\left(\frac{2c}{m} - \frac{4\pi^2V^2}{l_1^2}\right)^2 + \frac{16\pi^2\alpha^2V^2}{m^2l_1^2}\right]}, \qquad (6)$$

$$N = \frac{\Delta_N}{\Delta} = -\frac{\frac{2ch_o}{m}\left(\frac{2c}{m} - \frac{4\pi^2V^2}{l_1^2}\right) + \frac{16\pi^2\alpha^2V^2h_o}{m^2l_1^2}}{\left(\frac{2c}{m} - \frac{4\pi^2V^2}{l_1^2}\right)^2 + \frac{16\pi^2\alpha^2V^2}{m^2l_1^2}} \qquad (7)$$

Therefore, a mathematical apparatus has been developed to determine the optimal design and kinematic parameters of the front mounted haulm gatherer on the wheeled trailing tractor in the form of a final analytical expression. Application which allows determining the vertical movement of any point of its frame (including the lower end of the rotary cutter) with the vibrations of the botting machine during its operation affects the quality of the process.

The analysis of the dependences showed that the amplitude of the natural oscillations of the center of mass of the copying wheels of the haulm gatherer decreases with an increase in the speed of its movement to 3.0 m·s^{-1} and an increase in the design parameter from 1.05 to 2.10 m. This allows us to state that improving the quality of soil cultivation and using wide-swing aggregates allows reducing the oscillations of the cutting device of the haulm gatherer.

It is also determined that the frequency of forced oscillations of the center of mass will not exceed 10 s^{-1} in the whole range of agronomic speeds when using machines with a working width of more than 2.2 m.

Numerical modeling of the oscillatory characteristics of the front mounted hovering aggregate based on the integrated wheel tractor of traction class 3 showed that when choosing the optimal design parameters this oscillating system is capable of extinguishing the disturbing effect from the field surface. Thus, for example, at an aggregate speed of 3.5 m · s^{-1} the amplitude of the natural oscillations of the center of mass of the copying wheels of the haulm gatherer decreases by 2.2 ... 2.7 times in comparison with the height of the unevenness of the field surface equal 0.06 m.

CONCLUSION

1. Conducted analytical studies allowed to close the main issues related to the mechanical and technological fundamentals of the front suspension of the haulm gatherer on the wheeled tractor.

2. On the basis of the developed mathematical model of efficient aggregation of front mounted haulm gatherers on the wheeled tractors, it is determined that wheeled tractors of class 0.9 and 1.4 will provide sufficient and stable performance only when three- or four-row harvesting machines are assembled, and using a six-row machine It is possible with a specific resistance up to 2100 ... 2300 N · m^{-1}. Tractor class 3 provides productivity of 3,3 ... 3,5 hectares · h^{-1} when working with a six-row harvester, and the power reserve is enough for a root harvesting machine.

3. A mathematical model for predicting the loss of sugar-containing mass and remains of tops for different varieties of sugar beet, cultivation technologies and means of harvesting it has been developed. Thus, with a

mathematical expectation of m = 40 mm and a root-mean-square deviation of σ = 10 mm of the arrangement of the beet root heads, the rational height of the main continuous cut is h = 23.6 mm.

4. The dependence for the determination of structural and kinematic parameters of the front mounted haulm gatherer on the wheeled row tractor has been derived that allows to obtain a vertical movement of any point of its frame with the oscillations of the haulm gatherer during its operation. It is determined that when choosing the optimal design parameters and the speed of the unit = 3.5 m · s^{-1}, the amplitude of the natural oscillations of the center of mass of the copying wheels of the haulm gatherer decreases by 2.2 ... 2.7 times in comparison with the height of the unevenness of the field surface = 0.06 m.

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DETERMINATION OF THE LEVEL OF SOIL COMPACTION BY METHOD OF GUTTA-DIAGNOSTICAL INDICATION

E.J. Nugis, PhD & Dr.Sc.Eng

SCA ECOFILLER

By means of the method of gutta-diagnostical indication, i.e. estimation of the level of soil compaction has determined (first author E. Reppo), and thereafter it will be able to forecast the decrease of the crop yield. This methodological conception is based on the express-diagnostics method, field experiments and complex tests in laboratory conditions. To this end we are using the penetrometer, oedometer, strain-gage sensor (author E.P. Kuznetsova) and cereal test-culture which is as living measuring instrument for complex estimation of soil compaction. Also for estimation the influence of several kind tractors on soil the ratio of providing the agro-ecology were carried out.

Keywords: express-diagnostics and gutta-diagnostics method, soil compaction, estimation of tractor's pressure on soil.

INTRODUCTION

On the assumption of results investigations of soil compaction is one of the main part of general soil degradation due to the effect of anthropogenic factor [1, 2]. With this factor absent, the soil is in its natural state and controlled by natural processes taking place in nature. By the agro-ecologic estimation of soil compaction, such normal guttation state of a test-culture (for example barley) was taken as basis for evaluation.

Concerning soil compaction we are not in any case going to underestimate author's results investigations related both in the early and late period. The authors as Alakuku, L. and Elonen, P. (1996) [3], Arvidsson, J. and Håkansson, I. (1991) [4], Gysi, M., Klubertanz, G. and Vulliet, L. (2000) [5], Håkansson, I. (1994) [6], Liepiec, J. and Stepaniewski, W. (1995) [7], Medvedev, V.V. (1990) [8], Rusanov, V.A. (1998) [9], Kacygin, V.V. and Orda, A.N. (1977) [10], Kravchenko, V.I. (1986) [11], Mouazen, A.M. and Ramon, H. (2009) [12], Koolen, A.J. and van den Akker, J.J.H. (2000) [13], Soane, B.D., Dickson, J.W. and Campbell, D.J. (1982) [14], Söhne, W. (1953) [15], Skotnikov, V.A., Ponomariov, A.B. and Klimanov, A.B. (1982) [16] and finally Eds. of book B.D. Soane and C. van Ouwerkerk (1994) [17] deserve certainly full attention in any case.

In Estonia where up to the recent times intense agricultural use of land was practiced and where now the lands have been returned already to actual owners. It is of great importance in what state of machine degradation they are taken into economic use again. Every owner is striving to a sparing use of land. However, not everybody has a clear idea of how this should be done. Therefore it is expedient to work out methodology for estimation of soil compaction and also starting-points for carry out of an agro-ecological bearing capability (AEBC or $q_{a\text{-}ec}$) of soil which for Estonia in the process of development as well as for other Baltic States, should be possibly cheaper and most efficient.

MATERIALS AND METHODS

For determining the allowed on soils compaction and obtaining an adequate picture of the final results of soil vulnerability, the express method has been worked out [18]. This method is based on the principle of separation of gutta liquid (Fig. 1) at a constant temperature (23°C) and at up to 100 per cent of air humidity [19].

This is achieved in a hydrothermostat PTS-3. For water evaporator the water tanks are placed on the remnants of ordinary thermostat, which is needed for germination of seeds. Germinated seeds (5 pieces) are sown into cylinders of 8 cm in height and 6 cm in diameter.

In 48 hours for barley and in 52 hours for rice, 3 cm sprouts of whitish colour will spring up. On these sprouts dewdrops appear (Fig. 1).

At higher bulk densities the gutta liquid is totally absent (cylinder No 1, Fig. 1), on the assumption of the bulk density is a more than 1.70 g/cm^3 (or according the dimension of West-Countries 1.70 Mg m^{-3}). In this conditions the

Contact info: Murumäe põik 7, 75512 Saku, Harju County, Estonia, edvin.nugis@mail.ee

germs as the first stage of the seeds are unable of developing. The gutta liquid can easily be collected on filter paper where a blot appears. The area of the blot (mm^2) can be fixated by a planimeter (Fig. 2). For better fixation the contours of the blot, the filter paper should be treated with 5 per cent copper vitriol solution.

Fig. 1. Example of gutta liquids on the sprouts: in cylinder No 1 – soil is over compacted (not yet liquid); in cylinder No 2 - sparingly compacted; in cylinder No 3 – not compacted (actually the soil is loosening).

Fig.2. Determining the area of the blot (mm^2) by planimeter

For specifying the strain in soil at a depth of 8 cm in laboratory conditions, the oedometer was used (Fig. 3). By this apparatus the several level of bulk density is obtained.

Proceeding from the practical point of evolution of machine degradation of soil, data on the estimation of relative guttation (at the same time could be interpreted as relative crop yield) were taken as the basis.

The estimation of machine degradation of soil is based on compare the results of measuring of the strain in soil of depth 8 cm in laboratory and also about <10 cm at field [20].

Usually during laboratory test for determining the level of soil compaction as a rule the first test is the soil moisture or water test should be done. This test from smallest soil water content (FSM) through ripping moisture of capillary connection (RMC), smallest field capacity (SFC) (virtually the same as field capacity (FC)), and up to the maximum molecular field capacity (MMFC)[] (Reppo, 1980) we were carried out. Our experience has shown that there is a definite relation between SFC and FC which can be defined as SFC/FC = 1.13 [21].

Also it is important to observe in field conditions the soil penetration resistance or cone resistance. For this we have used Eijikelkamp Penetrologger (Fig. 4).

Fig.3. Oedometer for determining of the strain (kPa) in soil. The strain is measured by apparatus through strain-gage sensor (author E.P. Kuznetsova, AFI, compailed by Rein Põldoja, ECRI).

Fig. 4. Eijikelkamp Penetrologger for measuring of cone or penetration resistance (up to 70 cm), and at the same time is available to measure volumetric water or moisture content (up to 10 cm) [22].

By this apparatus we in field conditions have been observed also the one of important characteristics related soil volume trample (kN/m^3).

After laboratory tests we have organized the field experiments where we measured by Kuznetsova's sensor (diameter 30 mm and thickness 7 mm) with strain-gage the level of strain of the soil in <10 cm depth. In results of these experiments during moving the wheel of tractor over Kuznetsova's sensor we have obtained the dynamic strain of soil q_d in the field. Dividing q_d by q_{st} (the data of the specific pressure (kPa) of the wheels is obtained from the directory) we have obtained finally the ratio of the specific pressure k_{d}..

RESULTS AND DISCUSSION

It has been proved by investigations that when using of any wheel tractor where the it load is engendered a normal dynamic strain σ=160 kPa. Our investigations have shown that in the middle part of the wheel track the decrease of the crop yield may reach 62 ±9 per cent or 0.62 ±0.09 (Fig. 5, the diagram on the right side and above). In this case as a result the measuring of bulk density may reach 1.53 ±0.04 g/cm3 or Mg m^{-3}.

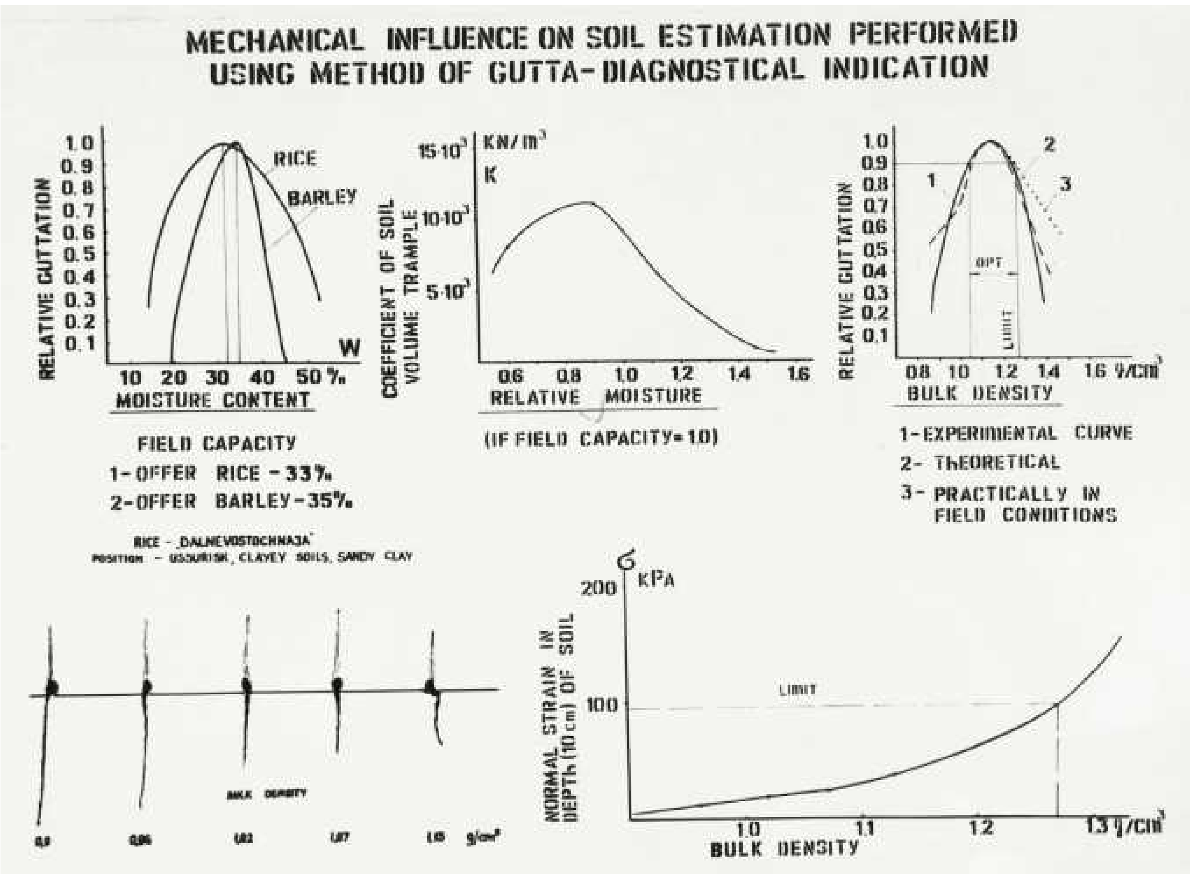

Fig. 5. Example of complex results for determination of the level of soil compaction by guttation method.

According this method (Fig. 5) we have obtained the similar results for such different cereals cultures as barley and rice related moisture or water tests in laboratory. Average level of the field capacity (FC) was 34 % which is equalized to 1.0 (W=34%=1.0). Thus, we have obtained the relative moisture content related coefficient of soil volume trampling (K) kN/m^3, see next diagram (in the centre and above). It is noteworthy to note that the maximum value of (K) occurs at the level 0.9 of FC (Field Capacity) or 0.9FC of relative soil moisture, i.e. real bigness W=0.9x34%=30.6%.While it is well known that at this level of moisture content the soil is a very vulnerable.

Given the fact that allowable limit (Fig. 5, the diagram on the right side and above) of soil bulk density at which the crop yield practically should not go down (the diagram on the right side) we can confidently set boundaries related sustainable level (limit) related above bulk density. At this diagram difference between experimental and theoretical curves is not significant, but in field conditions the cultivated plant has some possibilities to find more preferable conditions (the best selectivity) for survival, and this means that this evaluation should be considered. The picture on the left part and below of Fig. 5 gives again the confirmation concerning above.

Putting into practice of the normal strain σ=100 kPa as limit given has been effected on the example of tests with oedometer (Fig. 5, the diagram on the right side and below). If in comparison with wheeled (if inflation pressure 50 kPa) tractor in field conditions the strain σ of soil which has obtained by oedometer can be taken as the dynamic indicator which we could be obtained from in the field conditions when the tractor wheel moving over Kuznetsova's sensor. If maximum pressure q_d of wheel on soil did not exceed 60 kPa then a figuratively speaking the gait of wheel tractor is like agro-ecological. This kind of running gear corresponds to the conditions of agro-ecological bearing capability (AEBC or q_{a-ec}). Hereby, we should be noted that the moisture or water content of soil does not exceed 0.8 of FC or ~ 27 %. As far as ordinary wheel of tractor MTZ-82 (static pressure q_{st}=80 kPa, ratio of the specific pressure k_d=2.0, width of wheel 560 mm) the maximum compressive stress on soil of the order 160 kPa was obtained.

Working in Estonia with tractors from the West-countries such as Case IH CX MXM 155 (q_{st}=110 kPa, k_d=2.4, width of wheel 650 mm), John Deere 8120 (q_{st}=130 kPa, k_d=2.2, width of wheel 650 mm), Lamborghini Champion 150 DT (q_{st}=100 kPa, k_d=2.2, width of wheel 600 mm), Valtra Valmet 6200 (q_{st}=80 kPa, k_d=2.3, width of wheel 420 mm), Deutz-Fahr Agrotron (q_{st}=130 kPa, k_d=2.2, width of wheel 520 mm), Massey Fergusson 6290 (q_{st}=70 kPa, k_d=2.1, width of wheel 440 mm) also were used [23]. Also self-evident for these group tractors that allowable values of estimation parameters will be provided, at a soil water or moisture content not in excess of 0.8 of FC. Ignoring this requirement, a decrease of cereals yield and an adverse effect of soil compaction is likely to last for many years until natural biological processes, making for the restoration of the previous state, bring this biocenosis back into its state.

Finally, our opinion is that we should have some informative indicator by which is possible to estimate above mentioned tractor's group. If between strains in soil σ and pressure of tractor's wheel q_{di} to equalize, then we could be found for above mentioned tractor's group the ratio of providing the agro-ecology which is expressed by next equation:

$$\alpha_{ec} = (q_{d(max)} - q_{di})/(q_{d(max)} - q_{d(min)}) \qquad (1)$$

where $q_{d(max)}$ – maximum available dynamic press of wheel on soil (for example if it is be equal to 400 kPa) [23];

$q_{d(min)}$ – minimum available dynamic press of wheel on soil (for example if it is be equal to 60 kPa) [23];

q_{di} – current value of dynamic press of wheel on soil fixed during driving of wheel over strain gauge sensor in depth of <10 cm.

If $q_{di} = q_{st} \cdot k_d$ then we could be obtained the desired result. If for example to repeat again that for tractor MTZ-82 we have: $q_{di} = q_{st} \cdot k_d$ = = 80·2.0 = 160 kPa.

According above mentioned our opinion the main criterion is:

$$q_{d(min)} * q_{a-ec} * 60 \text{ kPa} \qquad (2)$$

The next our opinion is that at the same time we could be determined a sparing character of influence current wheel of tractor on soil. According equation (1) for tractor MTZ-82 we have α_{ec}= 0.71.

Finally, we can obtain also for tractors from the West in comparison with MT3-82 the definitive results related the ratio of providing the agro-ecology which is as series data from least up to mostly sparing character related influence wheel of tractors on soil:

Deutz-Fahr – α_{ec}= 0.34; Agrotron John Deere 8120 – α_{ec}= 0.34; Case IH CX MXM 155 – α_{ec}= 0.40; Lamborghini Champion 150 DT – α_{ec}= 0.53; Valtra Valmet 6200 – α_{ec}= 0.64; Case IH CX MXM 155 – α_{ec}= 0.74; Massey Fergusson 6290 – α_{ec}= 0.74.

CONCLUSIONS

As a result, it has been proved that in Estonia for several kind tractors the allowable values of dynamic pressure q_{di} (in depth of soil layer <10 cm) of tractor's wheel are as follows:

- MTZ-82 (q_{di} =160 kPa);
- Deutz-Fahr & Agrotron John Deere 8120 (q_{di} =290 kPa);
- Case IH CX MXM 155 & Lamborghini Champion 150 DT (q_{di} =(260 kPa);
- Massey Fergusson 6290 & Valtra Valmet 6200 (q_{di} =(170 kPa).

If the maximum values of strains σ, forming in the uppermost layer (<10 cm) of soil due to passing it by running gear of tractor, should not exceed the above-mentioned value of 60 kPa, and at the same time with the soil moisture of water content being 0.8 of FC (80 per cent of Field Capacity of soil) then is met the requirements of agro-ecological.

With the observance of the specified conditions of soil state, it is possible by method of gutta-diagnostical indication to maintain a soil sparing character of mechanical influence and agro-ecological bearing capability (AEBC or q_{a-ec}) of soil,

For each soil with its specific ecological background it is expedient to specify the allowable limiting values of agro-ecological bearing capability (q_{a-ec}) which is the final criterion for use of particular running gear mobile technical means.

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AUTOMATIC QUALITY CONTROL OF FLOW WHEAT TREATMENT

Volodymyr Diordiiev[1], Doctor of Engineering, Professor
Anton Kashkarov[1], PhD. in Engineering, Associate Professor
Hennadiy Novikov[2], PhD in Engineering

[1] Tavria State Agrotechnological University
[2] Private enterprise "Ascon"

The paper analyses the urgency of presowing wheat grain dressing. Measures for automatic control of the technological process of flow grain treatment according to its digital image are proposed. A laboratory method for assessing the treatment quality with the archiving of visually perceptible samples has been implemented. It is also possible to use a hardware method based on the pulse image acquisition, which reduces the requirements for speed and processing power of the control system, but does not allow an operator to visually assess the quality of treatment.

A device for obtaining a digital grain image in a pulse mode is proposed. The design of the device takes into account the technological process features of presowing grain processing. As a sensitive element, it has been proposed to use a CCD matrix protected by quartz glass and illumination with a white LED strip or a cold cathode lamp.

The developed methods allow for the first time to introduce an automatic method for controlling the operating modes of seed protectants, both with and without the use of dyes. The methods can be implemented in the laboratory with a selected sample from the grain flow, and directly in the grain flow in the automatic mode without physical sampling. The latter minimizes the contact of the operating personnel with the treated seed material.

At this stage of laboratory experiments, we can ascertain the dependence of coordinates of the vertex of the approximant parabola on the marker amount that is on the grain surface, which in the context of treatment indicates the protectant amount. In practice, this technique must be adapted to the colour of the dye.

The by-side practical result is the possibility of grain contamination control which may indicate a violation of presowing treatment modes.

Keywords: wheat treatment, automatic control, digital image, quality of treatment.

INTRODUCTION

To achieve high yields, the technological process (TP) of seed treatment with working solutions containing substances that promote growth, resistance to diseases and pests in the first days of growth is common. In practice, there is deep bacterial and fungal infection of the seed material, which exceeds 50% [6]. Phytopathogenic infections in the seed grain lead to deterioration of planting qualities, and the decrease in the rate of the plant growth and development [7].

If the agricultural and technical requirements are violated, the laboratory similarity of seeds may be decreased by 10% or more [7]. Field germination can be decreased even more. In accordance with agricultural and technical requirements, the minimum treatment degree is 85%, however, at optimal settings of TP it can reach 90-95% [9].

The purpose of the paper is to justify an information indicator for assessing the performance quality of technological equipment for seed treatment and the technical means for its implementation in production lines. The purpose can be achieved by using the law of large numbers. This is possible due to the use of modern microprocessor imaging tools (digital camera, scanner, web camera). In this case, it is possible to ignore the geometry of the grain and the TP modes, and also consider the treatment process using the "black box" method.

MATERIALS AND METHODS

Traditionally, the quality of seed treatment is controlled by laboratory methods, which are specified in the current normative documents of

Contact info: Melitopol, Ukraine, ea@tsatu.edu.ua
Akimovka, Zaporizhia obl, Ukraine, g.novikov@ukr.net

Standard of equipment inspection 01.1-37-429: 2006 “Seed treatment. General technical requirements”» and Engineering documentation 10 10.4-89 “Testing of agricultural machinery.

Machines for seed pretreatment. Testing program and methodology”. These methods are aimed at assessing the treatment equipment performance in laboratory conditions. They include a sequence of chemical experiments performed in a given amount of material, which is selected according to certain rules in order to minimize the measurement error [3, 9]. Such methods are long-term ones, require a special laboratory, qualified personnel and are influenced by the human factor significantly. In addition, the control is carried out after the completion of the TP, which makes it impossible to adjust its parameters in the automatic control system (ACS).

To evaluate the quality of seed treatment and develop the technique of hardware evaluation, we used a luminescent marker, the causative agent of which is ultraviolet irradiation, a visual inspection device and developed software for determining the uniformity and completeness of treatment [1]. Controlling the application of the marker in small doses was checked by electrisation of the disinfectant and grain with unlike charges.

The essence of the technique is to obtain a digital image of the sample during processing, or after it, under the same conditions of external illumination. Under laboratory conditions, the grain was lightened with an ultraviolet lamp and photographed in a dark room with a camera with the same settings. Diffused illumination at the level of the sample was 2 lux. The result was saved in a BMP graphic format file as a 24-bit colour drawing. To automate the experiments, special software was developed (Figure 1), the main tasks of which were: obtaining colour image parameters; obtaining graphs of a discrete series of colour distribution; export of data.

RESULTS AND DISCUSSION

Earlier, the team of authors proposed an electrical and technical complex for seed material treatment using electromagnetic fields [1, 5]. The proposed complex allows to improve the treatment quality, reduce grain damaging and energy costs for additional drying. The declared values are achieved due to grain falling through an electrically charged aerosol cloud.

The first task, which was solved on the basis of this method, is to make reliable conclusions

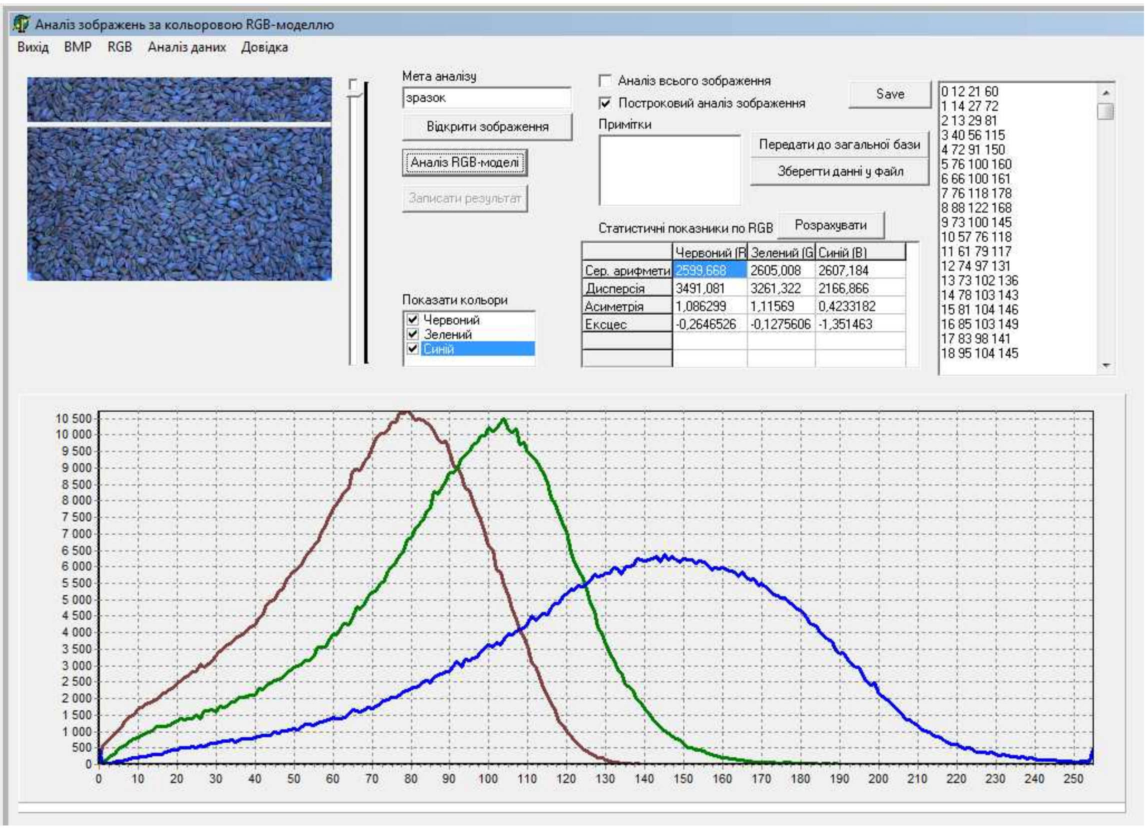

Figure 1. The dialog box of the program

on the protectant action mode, which would fully characterize the entire TP, on the basis of the tone distribution data which are obtained from the images of the grain flow. The theoretical solution of this question is based on the law of large numbers [4]. According to the research purpose, this law is used to determine the minimum image size sufficient for reliable estimation of TP.

Using Student's test it was proved that when working with a wheat image size of 750x750 px (scanning or photographing resolution of 300 dpi), the average values of tone frequencies statistically differ insignificantly. In accordance with the law of large numbers, the recommended number of scanned grains is 384 [4]. The nearest image to such quantity of grains, has the size 1000x1000. This size is taken as a basis.

The resulting distributions (Fig. 2) were analysed by statistical indicators, which characterize the total distribution and separate distribution for each tone. The analysis of statistical indicators of distributions has not allowed to distinguish the main colour and statistical parameter as a criterion of quality, because The average tone value, the dispersion of their distribution, the asymmetry and the kurtosis in all cases showed a linear correlation coefficient less than | 0.5 |.

The second variant of the analysis (evaluation of each tone) with the help of the linear correlation coefficient has turned out to be more informative (Figure 2). As a result of the calculations, the red colour does not have tones with the correlation coefficient greater than |0.8|. In turn, green and blue colours have a fairly large number of tone sections with the correlation coefficient greater than |0.9| (Figure 2).

In order to increase the reliability of the approximant, blue shades of 70 to 130 are used for further analysis. A parabolic function with a vertex at the extremum point most fully covers this range. In this range, the regression equation can be represented in the form of a parabolic function

$$y_{x2} = a_0 + a_1 \cdot x + a_2 \cdot x^2, \qquad (1)$$

where a_0, a_1, a_2 are the coefficients of the regression equation.

The coefficients of the regression equation (1) are determined by the method of least squares, for this we use the corresponding system of normalized equations [4]. For the analysis the arithmetic mean tone values of 4 samples of each experiment are used. The

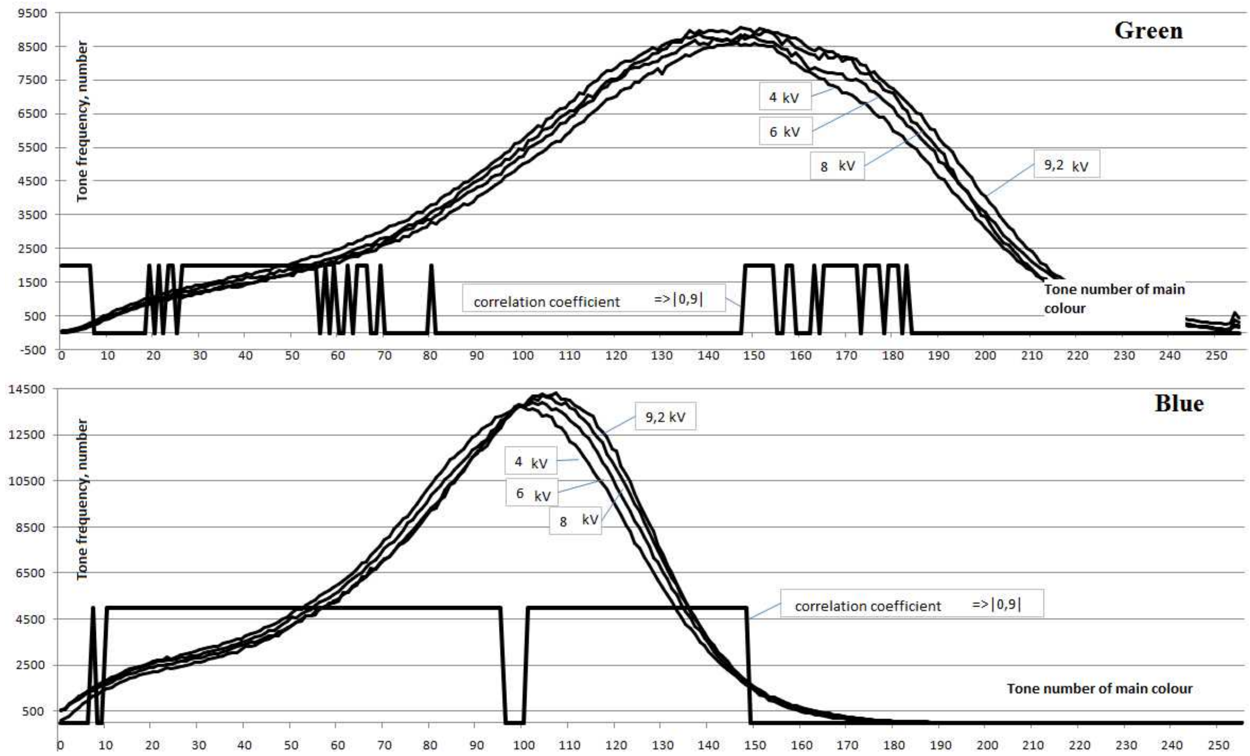

Figure 2. Distribution of image colour tones of seed materials under ultraviolet irradiation and aerosol treatment with voltage of 4, 6, 8 and 9,2 kV

samples do not have statistically significant errors for each tone, which were determined by the Student's test.

For practical use as an informative indicator, it is necessary to determine which of the parameters of the regression equation has the maximum coefficient of linear correlation, the relationship between processing parameters and the resulting coefficients of the regression equation. As an information indicator, the coordinates of the vertex of the parabola are used

$$\left(-\frac{a_1}{2a_2};\quad -\frac{4a_2 \cdot a_0 - a_1^2}{4a_2}\right), \qquad (2)$$

The results of the calculations show (Table 1) that it is most rational to use the coordinates of the vertex of the parabola as an informative indicator.

Table 1 - The value of the coefficients of the regression equations and the coefficient of linear correlation

Voltage, kV / Tone	4	6	8	9,2	Coefficient of linear correlation
a_2	-8	-8	-8	-8	0,94
a_1	458	480	507	510	0,987
a_0	6617	5869	5154	5014	-0,99
vertex x	29	31	33	34	0,997
vertex y	13300	13404	13544	13681	0,987

At this stage of the laboratory experiments, the dependence of the parabola vertex coordinates on the amount of the marker located on the grain surface is determined, which in the context of treatment indicates the amount of protectant. It should be added that most modern protectants have a dye that is allows you to evaluate the quality of treatment visually and rather roughly. In practice, this technique must be adapted to the colour of the dye.

In order to use this method under production conditions, it is necessary to develop a methodology and device for implementing automatic monitoring in the flow. This task is complicated due to the emergence of a number of technological issues: the location of the installation in the production line; technological operating conditions; the choice of the scanning device type; the possibility of timely maintenance and repair.

As a result of the analysis of external factors and adaptation of the measurement technique, pulsed obtaining of a digital grain flow image is proposed. In this case, an image is analysed with a width of 1 pixel, but not a static image of a given size. It is possible to receive information at a given periodicity. The hardware implementation is undemanding to the speed of information processing (Figure 3).

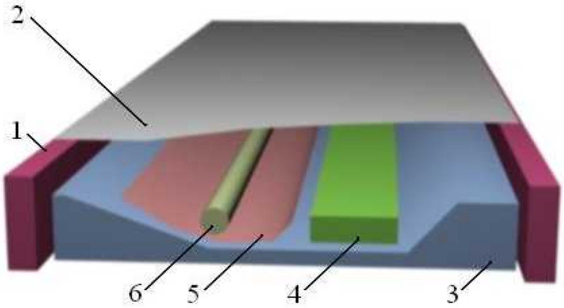

Figure 3. Construction of the device for original image obtaining: 1 - body; 2 - glass; 3 - base; 4 - sensing element (CIS matrix); 5 - reflector; 6 - light source (cold cathode lamp or LED strip).

proposed device works in this way: the body 1 is fixed, the glass 2 directly contacts the grain flow, which is minimally illuminated by an extraneous (external) light source at a predetermined time interval, the lamp 6 is turned on and provides the necessary illumination conditions for the operation of the matrix 4 by means of which an input signal is generated.

To implement the method for determining the parameters of grain treatment based on its digital image, it is necessary to select a scanning device taking into account the form of the matrix (4, Fig.3), as it is the most important part. Most modern scanners use two types of matrices (Table 2). The case of the CIS-scanner is flat, in comparison with a similar CCD-device (its height is about 40-50 mm).

If one takes into account that obtaining the initial data will be carried out in the flow of grain material, it is necessary to ensure that the most accurate original digital image is obtained for further analysis [1, 8]. This can be achieved by using a matrix with a greater depth of field.

The error in the spread of the levels of colour shades, which differ in the standard CCD matrices, is almost twice that of the CIS matrices, which indicates a qualitative difference between the actual colour and its digital representation of different types of matrices.

Table 2 - Advantages and disadvantages of scanning device matrices

Matrix type	Advantages	Disadvantages
CCD	High optical resolution (up to 2400 dpi) Long term of lamp operation Scanning quality Large scanning depth	High cost (with respect to CIS-matrices) Long lamp heating before scanning An additional power source.
CIS	Small size Fast start Low power consumption (USB-powered) Autonomy	Limited optical resolution (up to 1200 dpi) Influence of side lighting Small scan depth Poor scanning quality

To ensure the necessary quality of the image of grain material, the type and properties of the glass are taken into account, which separates the grain from the sensitive element of the optical system of the device. It should be taken into account that during the scanning of the grain in the flow, its possible damage (scratches, microcracks). Therefore, it is necessary to simultaneously consider the optical and mechanical characteristics of the glass. We propose to use quartz glass, which has a minimum refractive index and is most resistant to mechanical influences.

When discerning information about the grain flow is discerned, it should be taken into account that its reliability will depend on the width of the flow and the number of images. In this case, statistical indicators of the distribution of tones according to the length of the image are informative. You can only limit to the arithmetic mean. An additional advantage of this method is the possibility of determining additional technological parameters of the grain flow. At this stage, we are talking about contamination.

In accordance with the proposed method, a digital image of wheat is obtained at three points (Fig. 4). The diagram of the examined tones is presented in Figure 5. Standard statistical characteristics were used for their analysis (Table 3).

Table 3 - Results of statistical processing of diagrams (Figure 2)

	Weediness, % / Indicate	0	3	6	Coefficient of linear correlation
Red	Arithmetical mean	151	161	168	0,99
	Standard deviation	39,4	38,5	43,0	0,77
Green	Arithmetical mean	97,3	106	117	1,00
	Standard deviation	40,1	43,1	52,15	0,96
Blue	Arithmetical mean	77,6	82,9	91,9	0,99
	Standard deviation	31,4	34,3	40,27	0,98

Figure 4. Sample of digital image of "Zolotokolosa" winter wheat with plant impurities: 1 - weediness 0%; 2 - weediness of 3%; 3 - weediness of 6%

CONCLUSION

The automated control of the TP of flow rain treatment according to its digital image is realized. A laboratory and hardware method for controlling the quality of etching based on pulse imaging, which reduces the requirements for the speed and processing power of the control system, is presented.

The design of a device for obtaining a digital image of grain in a pulsed mode, considering the features of the technological process of presowing grain processing is proposed.

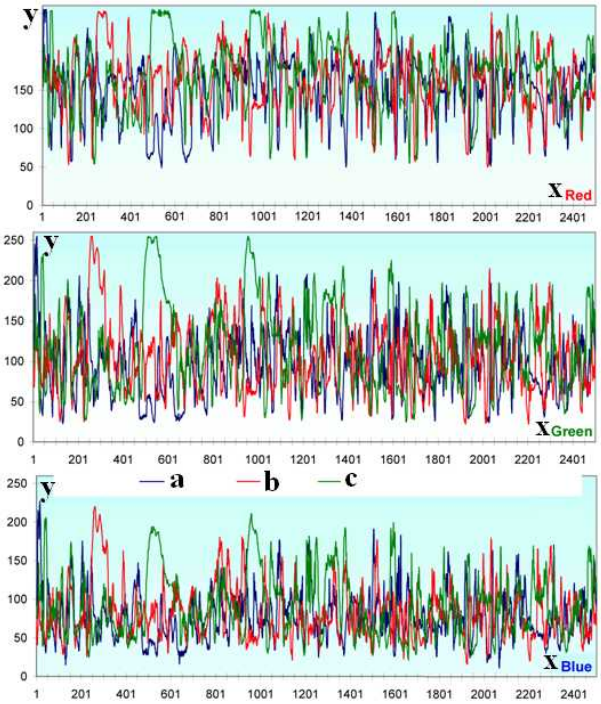

Figure 5. Examined toness of the RGB-model according to the image length (x is the image length, px, y is the tone number, a is the weediness of 0%, b is the weediness of 3%, c is the weediness of 6%)

The developed methods allow for the first time to introduce an automatic method for controlling the operating conditions of seed treatment, both with the use of dyes and without them. Control of the technological treatment process is carried out in the laboratory with sampling from the grain flow, and directly in the flow of grain material in automatic mode. The latter minimizes the contact of the staff with the treated seed material.

At this stage of laboratory experiments, we can ascertain the dependence of the coordinates of the vertex of the approximant parabola on the amount of disinfectant that is on the surface of the grain. In practice, this technique must be adapted to the colour of the dye. A by-side practical result was the possibility of controlling grain contamination, which may indicate a violation of presowing treatment modes.

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METHODOLOGY FOR DETERMINING THE PARAMETERS OF THE AIR FLOW IN A PNEUMATIC SEPARATOR WITH A CLOSED AIR SYSTEM

Evgeniy Mikhailov[1], Doctor of Technical Sciences,
Nadya Zadosnaia[1], eng.,
Nikolaiy. Rubtsov[2], Ph.D.,
Plamen Kangalov[3]

[1]Tavria State Agrotechnological University
[2]Melitopol State Pedagogical University
[3]University of Ruse "Angel Kanchev"

The paper considers the state of grain materials coming from grain harvesters for preliminary cleaning. Preliminary cleaning of grain is to separate large and air-separated impurities from the grain and thereby improve their flowability. This increases their safety during temporary storage. Pre-cleaning is necessary for seed and all food grain after harvesting.

The analysis of work of software tools and methods of their research is conducted. To a lesser extent, studies on the procedure for determining the parameters and operating modes of the scalper type air separator are presented, which determines the relevance of the study.

The device and the technological process of operation of a pneumatic separator with a closed air system are proposed, which pushes the task of developing a methodology for their investigation.

A special novelty in the study of airflow parameters of a pneumatic separator is a two-stage sedimentary chamber and a suction channel of the fan, which influence the validation of airflow parameters in the zone of fluidization of grain materials (ZM) and their pneumoseparation. An important role in this determines the injection airflow, which diametrically permeates a cylindrical sieve.

The state of the air flow structure and the analysis of factors ensuring the quality of cleaning grain material, constitute the main task of the study of the pneumatic separator.

A procedure for determining the airflow parameters of a scalper-type air separator is developed by studying the structure and air speed diagrams in the sections of the air distributor, the pneumatic separating and sedimentation chambers.

The structure and air speed diagrams in the air distributor are studied in five sections. The values of dynamic pressure and air flow are determined. When changing the live cross-section of the air distributor, different values of the angles of inclination of the middle moving and rear moving walls and the coefficient of the live section of the intensifier tray are taken into account.

Based on the obtained data, the working airflow rates are determined, the velocity diagrams are constructed, the structure hydraulic resistance of the pneumatic system is formed. This allows making adjustments to the definition of rational and optimal values of the parameters and modes of operation of pneumatic system. The result is increasing the efficiency of pneumoseparation and reduction of its energy consumption.

Keywords: pneumoseparation, grain, airflow, lots of grain, light impurities, dust.

INTRODUCTION

Grain material after receipt from the harvester includes a mixture of seeds of the main culture; third-party cultivated plants; impurities - damaged and immature grains; weed seeds; chaff; the living and the dead debris; impurities of mineral and organic origin.

The aim of preliminary cleaning of grain is to separate from the grain large impurities and thus improving their flow ability. This improves their safety during temporary storage. Pre-treatment is necessary for seeds and all food grains after harvest.

Adversely affects the machine productivity pre-cleaning the grain heap of high humidity

Contact info: Melitopol, Ukraine, +38(0619) 421265

and contamination [1,2,3]. It is caused primarily by the presence of small weed seeds in the grain material, which leads to its self-separation in kilns dryers. This negatively affects grain quality due to uneven heating and drying.

The grain heap when conducting the pre-cleaning is necessary to divide into factions. It is large and air-separable impurities up to 60% of all impurities, and processed grain with small remnants of non-separated impurities. The presence of impurities in length more than 50 mm are not allowed, and all foreign matter shall be not more than 5%. The presence of full grain in the waste should not exceed 0.02% of the total weight of main crop grain.

Grain cleaning machine pre-cleaning the grains are classified according to the following criteria: – mobility, divisibility rule grain mixture, the type of fan, the of type system air flow, airflow channel, the type of sieves, etc.

At the initial stage of cleaning the separation of components of the heap of grain takes place according to aerodynamic properties and especially the critical speeds of rotation. In this widely used phenomenon of motion of material particles in modern grain cleaning machines associated with the separation of the constituents of the heap. However, the quantitative regularities of the motion of bodies taking into account the resistance of the air environment and require additional research [4-9].

Installation and definition of parameters and regimes of operation of any grain-cleaning machines are an integral part of any study.

Special interest represent a pneumatic grid separator of a grain heap with a closed air system [5], where a device that allows dividing the air flow into two components - separating and feeding - is of great importance.

In the field of grain cleaning, the transfer of a grain heap into a fluidized state is presented in paper [5]. The grain mixture moves along the damper, and the air flow, supplied by the upper channel, passes through the perforated surface of the shutter and the grain layer.

In work [5], the grain material is fed into the feeding device of the pneumatic separating channel by the charging device. On a perforated inclined plane, the grain material is liquefied by an air stream, which is pumped by the fan through the air supply channel. As a result, light impurities "float up" to the surface of the grain material and enter the air-separation channel above the input zone of the grain part of the starting material.

In work [5] the technique of experimental studies of the separation process on an inertia-gravitational lattice separator is considered, where the determination of physicomechanical properties of grain is envisaged. The mathematical models were tested for adequacy. The regularities of grain sifting through grating sieves are studied depending on the main parameters and operation modes.

To a lesser extent, studies on the procedure for determining the parameters and operating modes of the scalper type air separator are presented, which determines the relevance of the study.

PURPOSE OF THE STUDY

Development of a technique for determining the airflow parameters of a scalper-type pneumatic separator by studying the structure and air speed diagrams in the sections of the air distributor, the pneumatic separating and sedimentation chambers.

METHODS OF RESEARCH

A special novelty in the study of airflow parameters of a pneumatic separator is a two-stage sedimentary chamber and a suction channel of the fan, which influence the validation of the air flow parameters in the zone of fluidization of the GM and its pneumo-separation. An important role in this determines the injection airflow, which diametrically permeates a cylindrical sieve.

The state of the air flow structure and the analysis of factors ensuring the quality of cleaning grain material, constitute the main task of the study of the pneumatic separator.

Determination of airflow rates is provided by the technique described in the works of Veselov, SA. [10] and [11]. The structure of the air flow is studied in cross sections perpendicular to the direction of the air flow. To determine the air flow parameters, it is supposed to use devices - the micro-manometer MMN-240 (MMN-2400) with a Pitot-Prandtl tube or a pressure tube of the NIIOGAZ design, a TTM-2-02 thermo-anemometer, thermo-anemometer TTM-2-02, hot-wire anemometer KIMO VT 50, taking into account DSTU ISO 6584: 2003.

RESULTS

Based on the carried out studies, a pneumatic separator is proposed, the technological scheme of which is shown in Fig. 1 [11,12]. The technological process of the pneumatic separator is carried out as follows. The air flow from the diametrical fan 1, driven by the direct-current electric motor 2 and the belt drive 3, is directed to the air distribution unit 5. The air flow, due to the control lever of the middle movable wall 6, is distributed to the louvers of the air distributor 7 and the intensifier tray 10.

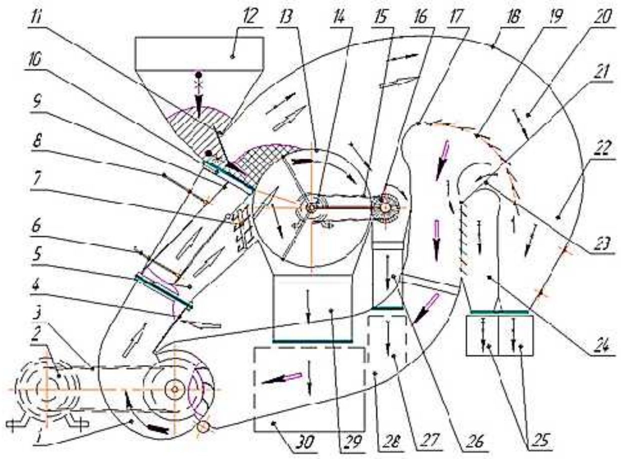

Figure 1. Technological scheme of pneumatic separator

1 - fan diametric; 2 - DC motor; 3 - fan drive; 4 - additional airflow inlet louvers in the fan; 5 - air distributor; 6 - control lever of the middle movable wall; 7 - air distributor blinds; 8 - control lever of the rear movable wall; 9 - extension of the rear movable wall; 10 - tray-intensifier; 11 - shutter of the hopper; 12 - bunker; 13 - cylindrical sieve; 14-motor-reducer; 15 - brush cleaner drive; 16 - brush cleaner; 17 - airflow cut-off; 18 - shell of the air channel of the sedimentation chamber; 19 - the working surface of the blinds of the 1st stage of cleaning; 20 - air channel of the 1st stage of purification; 21 - the surface of the blinds of the 2nd stage of cleaning; 22 - sedimentation chamber of the 1st stage of purification; 23 - input channel of the 2nd stage of purification; 24 - sedimentation chamber of the 2nd stage of purification; 25 - bunker of impurities of the 1 st and 2 nd stages of the sedimentation chamber; 26 - the channel and the valve for the withdrawal of large impurities; 27 - bunker of large impurities; 28 - the suction channel of the fan; 29 - channel and valve of the purified grain material; 30 - bunker of purified grain material.

The supply of heap coming from the hopper 12 is controlled by a shutter 11. By changing the position of the extension of the rear movable wall 9, the fluidization state of the grain heap on the tray-intensifier is provided. Here, segregation is carried out - the grain, as the heavier fraction, descends into the lower layer, and the light impurities (straw, unmilled ears) - into the upper layer. Due to the rotation of the cylindrical sieve 13, which is driven by the geared motor 14, the brush cleaner 16 is rotated simultaneously through the drive 15. The grain is spilled through the sieve and enters the hopper 30 through the channel of the purified cereal material 29. Large impurities (straw,ear and others) due to the rotation of the cylindrical sieve are moved to the area of the brush cleaner 16 and through the channel of large impurities 26 enter the bunker of large impurities 27. The air flow is regulated by the louvers 7, pierces the cylinder sieve and partly grain pile. The air-separated contaminants move through channel 20 and enter the zone of the sedimentation chamber of the 1st stage of purification 22. Under the action of centrifugal forces and gravity forces, light impurities (dust, small particles of straw) are pressed against the shell 18 and along the wall of the body moves to the impurity chamber 25. Due to the vacuum created under the working surface of the louvers of the I and II stages of the cleaning of the sedimentation chamber, the air flow is directed to the suction duct of the fan 28. The air flow in the fan is equalized by means of louvers 4. Light impurities enter through the louvre 19 into the inlet channel of the second stage of purification 23 and further into the sediment chamber of the II stage of purification, where they finally settle in the hopper 25. Thus, a closed cycle of operation of the air separator is carried out.

To conduct research, the technological scheme of the pneumatic separator (Fig. 1) will be conditionally divided into two zones - the zone of the air distributor and the pneumatic separating chamber (Fig. 2), and the zone of the sedimentation chamber (Fig. 3). The separation zone is taken along the Y-axis, passing through the center of the cylindrical sieve 13. The scheme of the laboratory-production plant for removing the characteristics of the air flow in the zone of the air distributor and the pneumatic separating chamber is shown in Fig. 2.

The scheme of the laboratory-production unit for removing the characteristics of the air flow in the zone of the sedimentation chamber is shown in Fig. 3.

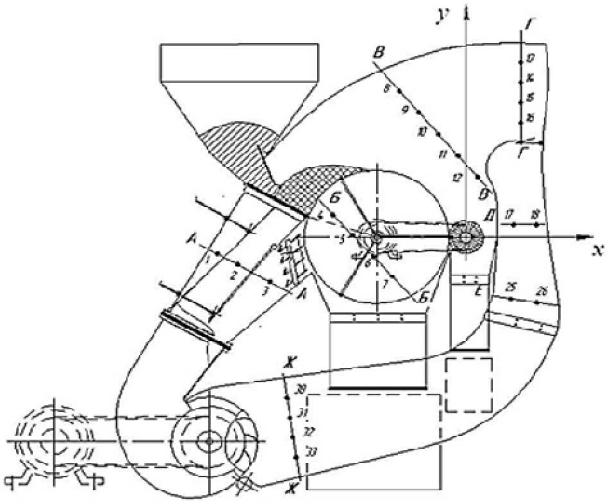

Figure 2 - Scheme of a laboratory-production plant for removing the characteristics of the air flow in the zone of the air distributor and pneumatic separating chamber.

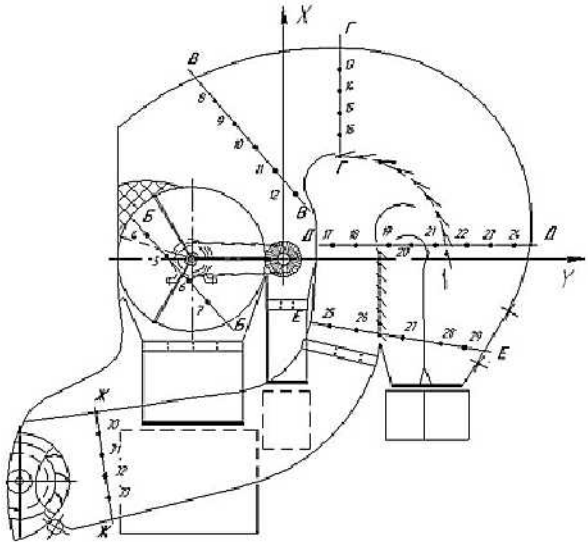

Figure 3 - Scheme of the laboratory-production plant for removing the characteristics of the air flow in the zone of the sedimentary chamber.

In the zone of the air distributor and the pneumatic separating chamber it is suggested to take into account and change the following factors (Fig. 1):

-fan speed;

-the angle of inclination of the air flow leaving the air distributor blind to the horizontal;

-the angle of inclination of the rear movable wall of the air distributor to the rear fixed wall;

-the angle of inclination of the moving middle wall to the fixed middle wall of the air distributor;

-length of the intensifier tray;

- the opening value of the hopper flap.

In the zone of the sedimentary chamber, it is proposed to take into account and change the following factors (Fig. 1):

- fan speed;

- the area of the "live section" of the blinds of the I-th stage of cleaning;

- the area of the "live section" of the blinds of the second stage of cleaning;

- the opening value of the hopper flap.

To assess the quality of the pneumatic system, we take the completeness of the separation of large, airborne impurities and the loss of high-grade grain into waste.

As an example of placement of cross-sections for measuring airflow parameters in an air distributor, refer to figure 4. Here is a diagram of a laboratory-production installation for determining the main parameters and operating modes of the supply and separation components of the air distributor.

The structure and airspeed diagrams of air velocities in the air distributor are studied in five sections. The values of dynamic pressure and air flow are determined. When changing the "live section" of the air distributor take into account the different values of the angles of inclination of the middle moving and rear moving walls, and the coefficient of the live section of the intensifier tray. Measurements of the air flow parameters are carried out in accordance with [10, 11] in the sections: 0-0 - the cross-section for measuring the dynamic pressure at the inlet to the distributor

I-I - cross-section for measuring the dynamic pressure under the intensifier tray;

II - II - cross section for measuring the dynamic pressure above the intensifier tray;

III - III - section of the measurement of dynamic pressure under the louvered air distributor;

IV - IV - cross section for measuring the dynamic pressure in the separating zone of a cylindrical sieve.

Based on the obtained data, the working airflow rates are determined, velocity profiles are plotted, and the structure of the hydraulic resistances of the pneumatic system is formed. This allows you to make adjustments in determining the rational and optimal values of the parameters and operating modes of the pneumatic system. As a result, it is planned to increase the efficiency of the pneumatic separator and reduce its energy intensity.

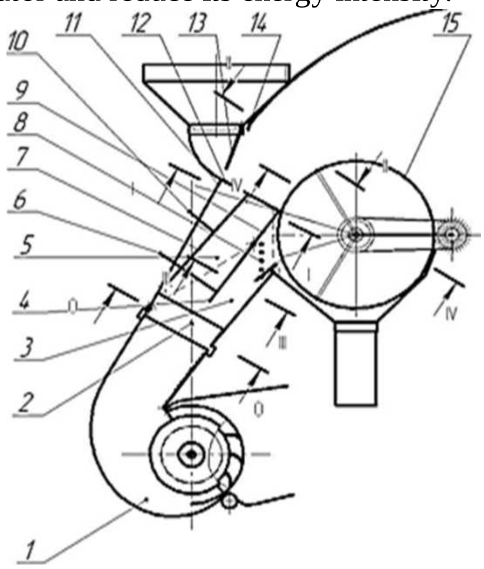

Fig. 4 - Scheme of the laboratory - production installation for determining the main parameters and operating modes of the supply and separation components of the air distributor.

1 - the fan diametric; 2 - device of an air distributor; 3 - separating component of the air distributor; 4 - middle movable wall; 5 - feeding component of the air distributor; 6 - the regulator of change of an inclination angle of an average mobile wall; 7 - movable rear wall; 8 - air distributor louvered; 9 - fixed middle wall; 10 - the regulator of a change in the angle of inclination of the rear movable wall; 11 - rear wall; 12 - tray-intensifier; 13 - power supply; 14 - bunker; 15 - cylindrical sieve.

CONCLUSIONS

1. The state of grain materials coming from grain harvesters for preliminary cleaning is considered.

2. The analysis of the work of the software and the methods of their research, which testifies to the small number of studies of the scalper type pneumatic separators, is conducted.

3. The device and the technological process of operation of a pneumatic separator with a closed air system are proposed, which raises the problem of developing a methodology for their investigation.

4. The technique for determining the airflow parameters of the scalper type air separator is developed by studying the structure and air speed diagrams in the sections of the air distributor, the pneumatic separating and sedimentation chambers.

On the basis of the data obtained, the operating speed of the air flow is determined, and the structure of the hydraulic resistances of the pneumatic system is formed. This allows you to make adjustments in determining the rational and optimal values of the parameters and operating modes of the air separator.

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THE SUBSTANTIATION OF THE OPTIMUM TYPE OF THE MACHINE FOR THE AGGREGATION WITH THE TILLAGE SOWING COMPLEX

Artur Kushnarev[1]*, Doctor of Technical Sciences, Professor,*
Vitalij Serbiy[2]*, Candidate of Technical Sciences, Senior Researcher*

[1]Tavria State Agrotechnological University
[2]NSC «IAEE»

The method for the optimum power determination and material capacity of a tractor for a specific width of the tillage sowing complex and a given field area is given in the article. The recommendations on the compilation of machine-tractor units in the composition of the tillage sowing complex are given.

Keywords: machine, tractor, complex, tillage, sowing

INTRODUCTION

The strategy of machine and technological support of agricultural production in Ukraine should ensure transition to low-cost resource-saving technologies using highly efficient tillage units and sowing complexes.

In the field of plant technology, large transformations should be carried out by introducing into the technological process of crop production of complex units - sowing complexes, for the purpose of performing in a single processing pass, two or three levels of application of fertilizers, treatment with herbicides, precise sowing of various plants seeds and subsequent soil compaction in a row. Such technical solutions should reduce to 2.5 times the necessary number of machines for technologies for the production of plant products by 30-60% to reduce the metal capacity of the machinery fleet by 10-15% to reduce the cost of production [Kryuchkov M.M, 2013].

Agrotechnical methods, units and machines used in effective resource-saving soil protection technologies should maximize the positive impact of natural factors and resources. The main thing is a technique that works effectively, minimally affects the soil, ensures the preservation of its fertility, microflora and fauna, retains moisture and eliminates erosion. Its use requires a minimum of chemicals to protect plants against diseases and weeds. This is a step towards highly effective resource-saving soil protection technologies.

The basis of the modern tractor market is the unified mobile machines of the wheel formula 4k4a of various sizes with variables in a wide range of mass - energy parameters. A special feature of the adaptation of such tractors in zonal tillage, fertilization and sowing technologies is the choice of the optimum tractor power and the gradual replacement of the operational mass by ballasting, installing the dual wheels and the use of loaders [Selivanov N.I., 2013; Pastukhov V.I., 2001; Fortuna V.I., 1979; Khrobotov S.N., 1973; Kurochkin I.M., 1996].

In the works of Selivanov N.I. 2015, the ballasting conditions of wheeled 4k4a tractors with the established energy potential for adapting to modern technologies of tillage are grounded. Models are formulated; an algorithm for rational ballasting and a nomogram for determining the parameters of additional ballast are developed. When selecting and preparing tractors of different manufacturers and sizes in operation, the method of determining the degree of ballasting of a tractor with an optimally selected power with a certain slippage index and using the resistivity of the tillage sowing complex, the working width and the geometrical parameters of the field is more versatile.

MATERIALS AND METHODS

For the objective function to justify the capacity of the machine, we take the minimum of the energy costs listed:

$$Q = \frac{N_{н} \cdot T_{р} + N_{х} \cdot T_{х}}{W_{см} \cdot (T_{р} + T_{х})},\ Q \rightarrow min \qquad (1)$$

where: $N_{н}$ – rated capacity, kW;
$N_{х}$ – - idle power, kW;
$T_{р}$ – spent time on working strokes, h;

Contact info: Melitopol, Ukraine, tmm11@yandex.ua

$T_х$ – spent time on idling, m;
$W_{см}$– replaceable productivity of the unit, ha/h.

The capacity of the unit is determined by the well-known formula: $W_{зм} = 0.1 \cdot B \cdot \vartheta_р \cdot \tau$. Where: τ - the coefficient of working time use [Kirtbaya Yu.K., 1961; Ageev L.E., 1978; Guskov V.V., 1966; Kutkov G.M., 2004; Zavora V.A., 2010; Serbii V.K., 2011].

$$\tau = \frac{T_р}{T_р + T_х} = \frac{1}{1 + \frac{T_х}{T_р}} \qquad (2)$$

$$T_р = \frac{L_р \cdot n_р}{10^3 \cdot \vartheta_р} \qquad (3)$$

$$T_х = \frac{L_х \cdot n_х}{10^3 \cdot \vartheta_х} \qquad (4)$$

where: $L_р$ – the length of the line, m, (we take $L_р = const \approx 500$ м);
$\vartheta_х$– the speed of the unit at idling, km/h (we take $\vartheta_х = 3{,}5$ km / h);
$n_р$– the number of working strokes, pcs.;
$n_х$– the number of idling, pcs. $n_х = n_р - 1$;
$L_х$ – the length of idling, m (Fig. 1).

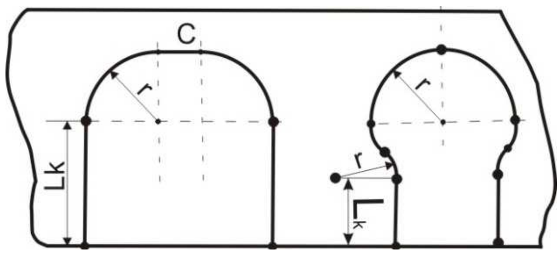


Figure 1. The execution diagram of semi-circular and pear-shaped movement in the zone of the turn strip

To determine the working stroke ratio, we calculate the length of idling. The condition for performing a semicircular mode of motion is $2 \cdot r \le B$. And the parameters of the trajectory of motion are determined by the system:

$$\begin{cases} 2 \cdot r = B \to C = 0 \\ 2 \cdot r < B \to C = B - 2 \cdot r \\ L_х = 2 \cdot L_к + 2 \cdot r + C \end{cases} \qquad (5)$$

The condition for performing the pear-shaped mode of motion is: $2 \cdot r > B$. And the length of idling is determined by the expression:

$$L_х = 2 \cdot L_к + 2 \cdot r + 4 \cdot \frac{\pi \cdot r \cdot \arccos\left(1 - \frac{2 \cdot r - B}{4 \cdot r}\right)}{180} \qquad (6)$$

where: $L_к$ – the kinematic length of the unit, m;
r – turning radius of the machine, m;
B – working width of the tillage sowing complex, m.

To determine the productivity of the unit and the traction resistance (7) of the tillage sowing complex, we calculate the unit speed according to the expression (10) after some transformations:

$$P_{кр} = B \cdot \left(P_{уд} + \varepsilon \cdot \rho \cdot S \cdot \left(\vartheta_р^2 - \vartheta_0^2\right)\right) \qquad (7)$$

where: $P_{уд}$ - specific tractive effort, kN / m;
ϑ_0^2 – the initial speed of the unit, where there is no significant increase in the traction resistance of agricultural machinery, m / s;
ε – is a coefficient that takes into account the continuity of the treatment and part of the particles to which the velocity is transmitted $\vartheta_{р_i}^2$;
ρ– the soil density, kg / m3;
S – is the cross-sectional area of the treated soil by the working bodies per running meter of the width of the machine, m2 / m;
$\vartheta_р^2$ – the design speed of the unit, m / s.

$$\begin{cases} \vartheta_р = \frac{N_{кр}}{P_{кр}} \\ \tilde{N}_н = N_{кр} + P_f \cdot \vartheta_р \\ B = \frac{P_{кр}}{P_{уд} + \varepsilon \cdot \rho \cdot \left(\vartheta_р^2 - \vartheta_0^2\right) \cdot S} \end{cases} \qquad (8)$$

where: $N_{кр}$– hook capacity of the unit, kW;
P_f – is the force is necessary for the rolling of the power facility, kN;

$$P_f = G_{зч} \cdot f \qquad (9)$$

where: $G_{зч}$ – coupling weight of the machine, kN;
f – is the coefficient of rolling resistance of the machine.

After the substitutions in system (8) we obtain:

$$B = \frac{\tilde{N}_н - P_f \cdot \vartheta_р}{\vartheta_р \cdot \left(P_{уд} + \varepsilon \cdot \rho \cdot S \cdot \left(\vartheta_р^2 - \vartheta_0^2\right)\right)} \qquad (10)$$

We replace α = ε · ρ · S. From equation (10), we express the unity velocity θ_ρ:

$$\vartheta_р = Z - \frac{1}{3 \cdot Z}\left(\frac{P_{уд}}{\alpha} - \vartheta_o^2 + \frac{P_f}{B \cdot \alpha}\right), \qquad (11)$$

According to expression (7), having the actual speed of the unit, it is possible to

$$Z := \left(\sqrt{\frac{P^3}{27 \cdot \alpha^3} - \frac{\upsilon o^6}{27} + \frac{P \cdot \upsilon o^4}{9 \cdot \alpha} + \frac{N^2}{4 \cdot B^2 \cdot \alpha^2} + \frac{Pf^3}{27 \cdot B^3 \cdot \alpha^3} - \frac{P^2 \cdot \upsilon o^2}{9 \cdot \alpha^2} - \frac{Pf^2 \cdot \upsilon o^2}{9 \cdot B^2 \cdot \alpha^2} + \frac{P^2 \cdot Pf}{9 \cdot B \cdot \alpha^3} + \frac{P \cdot Pf^2}{9 \cdot B^2 \cdot \alpha^3} + \frac{Pf \cdot \upsilon o^4}{9 \cdot B \cdot \alpha} - \frac{2 \cdot P \cdot Pf \cdot \upsilon o^2}{9 \cdot B \cdot \alpha^2}} + \frac{N}{2 \cdot B \cdot \alpha}\right)^{\frac{1}{3}} \qquad (12)$$

calculate the tractive resistance and determine the utilization factor of the coupling weight of the power facility, $\varphi_{сц} = \frac{P_{кр}}{G_{сц}}$ and the slipping δ, and then you can calculate the power used, taking into account slippage:

$$N_{вп} = \widetilde{N}_{н}/(1-\delta) \qquad (13)$$

Determine the nominal capacity of the machine:

$$N_{н} = N_{вп}/\eta_{н} \qquad (14)$$

where: $\eta_{н}$ =0,9 – coefficient of utilization of the rated power of the tractor.

To automate the process of searching for the optimal power of the machine, we compile a flowchart of the algorithm and a program in the VBA programming language.

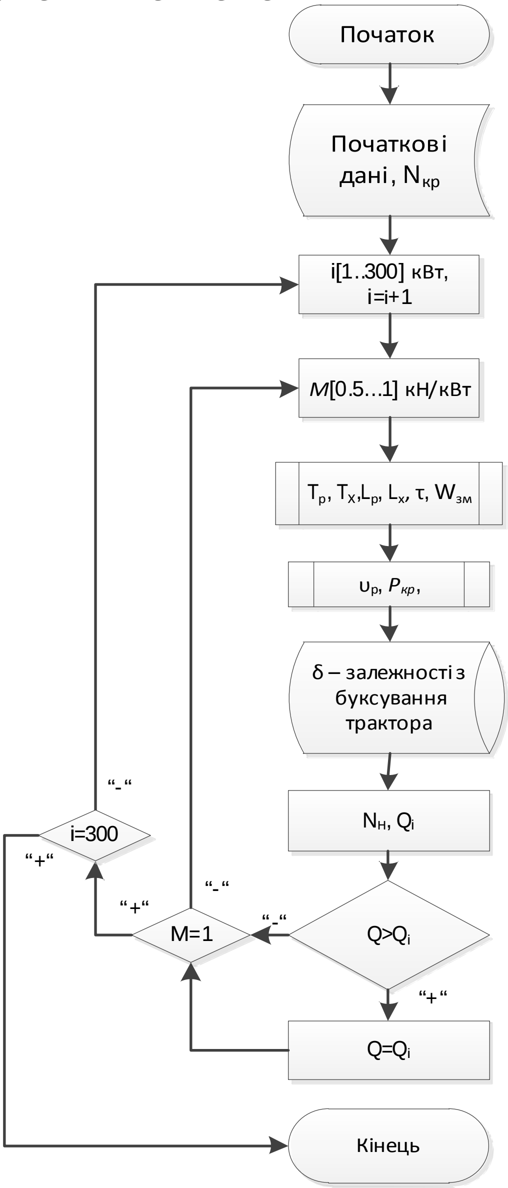


Figure 2. Block diagram of the algorithm for simulating the power capacity of the machine in a unit with a sowing complex $N_н$, kW

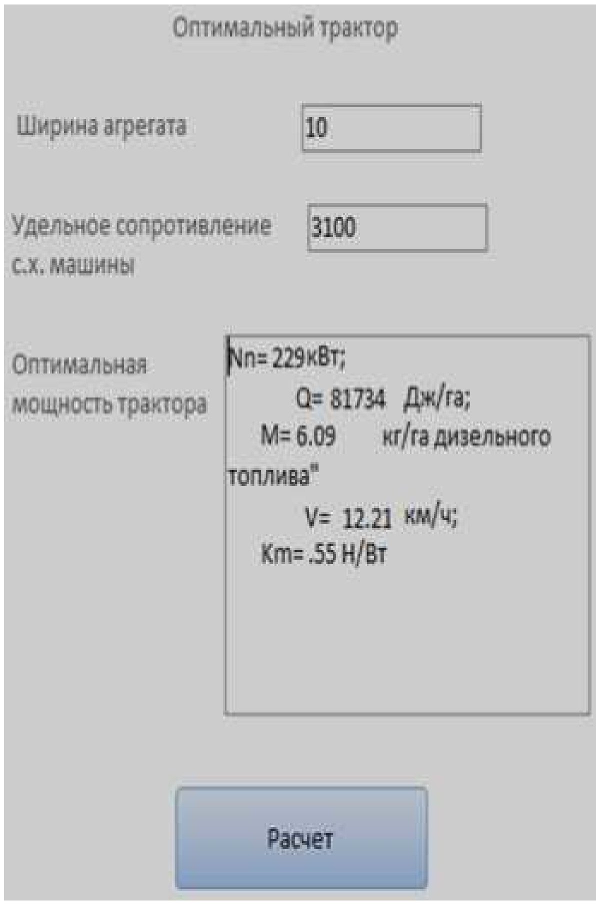


Figure 3. Screenshot programs for calculating the optimal type of the machine in the unit with the sowing complex.

The dependence of the power of the machine on the width of the capture of the tillage sowing complex (Figure 4) was approximated:

$$N_{н} = 10.8 \cdot B \qquad (15)$$

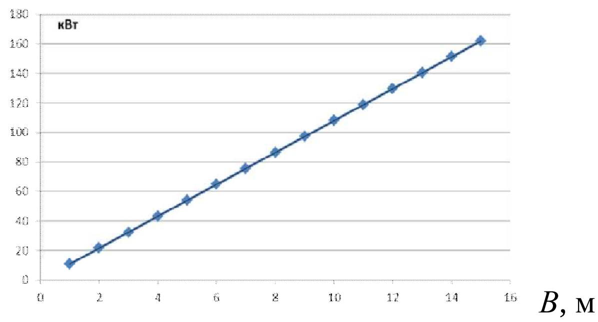


Figure 4. The graph of the dependence of the optimum power of the machine on the width of the capture of the tillage sowing complex by the criterion of the minimum fuel consumption

We will also find the optimal material capacity by using the simulation method on the block diagram (Fig. 2), where this algorithm is incorporated. And we will give the essence of the method of ballasting according to a particular program (Fig.3) of the required material capacity of the machine.

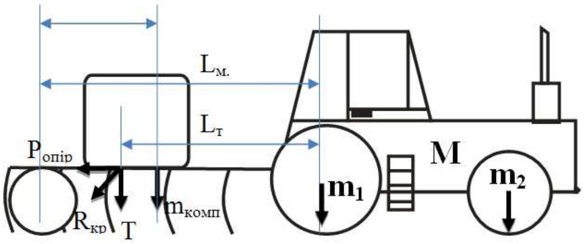


Figure 5. The diagram of the ballasting of the machine in the unit with a tillage sowing complex

Let's determine the mass of ballast, which must be added to the mass of the machine:

$$\Delta M = M_p - M, \quad (16)$$

where: M_p – is the estimated mass of the machine, kg;

M – is the actual operating mass of machine, kg.

$$M = m_1 + m_2, \quad (17)$$

where: m_1 – is the part of the mass of the machine that falls on the rear axle, kg;

m_2 – is the part of the mass of the machine, which falls on the front axle, kg.

According to the diagram shown in Fig. 5 the part of the mass of the tillage sowing complex is transferred to the rear axle of the machine, in addition, the vertical component of T reaction of the traction resistance of the complex $R_{кр}$ additionally loads the rear axle. The influence of the mass of the tillage sowing complex is expressed as follows:

$$M_{компл} = m_{компл} \cdot \frac{L_{ц.м.}}{L_м} + \frac{R_{кр} \cdot sin\alpha}{g} \cdot \left(1 - \frac{L_т}{L_м}\right) \quad (18)$$

So, we rewrite expression (17) and (16)

$$m_1 = m_1 + M_{компл}, \quad (19)$$

$$M = m_1 + m_2 + M_{компл}, \quad (20)$$

$$\Delta M = M_p - m_1 + m_2 + M_{компл}. \quad (21)$$

where: ΔM – the total weight of ballast, kg.

As is known the machine with a wheel formula 4K2, 4K4 loses its controllability with the coefficient of load of the front wheels is less than 0.2 [4].

Therefore, let's check the condition of the unit:

$$\frac{m_2}{M} \geq 0{,}2, \quad (22)$$

If the condition (22) is satisfied, then the balancing of the machine will have the form:

$$\Delta x = \frac{m_2}{M} - 0.2, \quad (23)$$

$$\Delta M_x = \Delta M - M \cdot \Delta x, \quad (24)$$

$$\Delta m_1 = M \cdot \Delta x + \frac{\Delta M_x}{2}, \quad (25)$$

$$\Delta m_2 = \frac{\Delta M_x}{2}, \quad (26)$$

where: Δm_1 – is the mass of ballast, which must be loaded rear axle, kg;

Δm_2 – is the mass of the ballast, which must be loaded with the front axle, kg;

Δx – is the mass of the ballast, which is necessary to load the front axle to meet the minimum value of the index of the machine manageability;

ΔM_x – is the total mass of the ballast for the installation on the machine, kg.

If the condition (22) is not satisfied, then the machine balancing will be performed as follows:

$$\Delta x = 0.2 - \frac{m_2}{M}, \quad (27)$$

$$\Delta m_1 = \frac{\Delta M_x}{2}, \quad (28)$$

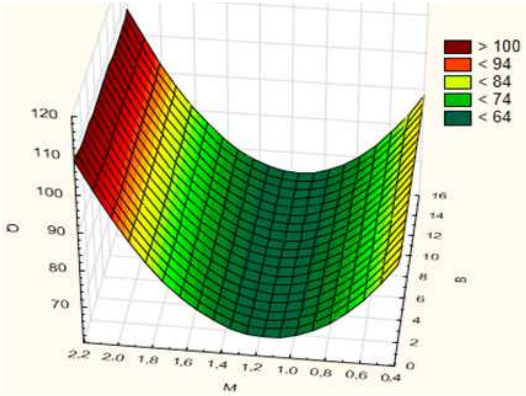
$$\Delta m_2 = M \cdot \Delta x + \frac{\Delta M_x}{2}. \quad (29)$$

Modeling the work of the tillage sowing unit according to the above algorithm in the program (Fig.3) we received the operating data of its functioning with various operational parameters at a speed of work from $\vartheta_p = 2 \ldots 4$ m/s.

When we have analyzed Fig. 6-7, we established that the most effective is the material capacity, which is equal to unit. At the same time, the optimum, i.e. the lowest fuel consumption is attained.

CONCLUSIONS

According to the developed methodology, a program has been created for the calculating of the optimal type of the machine. The criterion of the optimization is adopted the minimum of the given energy costs. It is determined that for the specific size of the tillage sowing complex, the optimal machine should be selected in terms of capacity together with its ballasting. The most effective in the unit with a tillage sowing complex is the machine with a material capacity coefficient equal to 1.



H/W

Figure 6. The surface of the response of the dependence of the reduced fuel costs on the material capacity of the machine and the width of the tillage sowing complex

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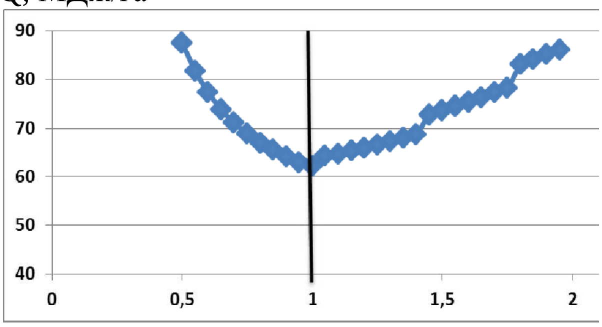

Figure 7. The graph of the change in the given energy costs from the material consumption of the machine for B = 6 m

Modern tractors have a material capacity ratio of 0.55-0.59. That is, the optimal machine in terms of fuel economy is that one whose mass is 2 times greater than that of modern machines.

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