Technical sciences

BULLETIN OF POLTAVA STATE AGRARIAN ACADEMY

ISSN: 2415-3354 (Print)
2415-3362 (Online)

https://journals.pdaa.edu.ua/visnyk

original article | 621.867.133 | **doi: 10.31210/visnyk2020.03.31**

RESEARCH ON THE INFLUENCE OF THE OPERATING MODES OF COMBINE HARVESTER'S TRANSPORTATION LINES ON THE QUALITY OF GRAIN THRESHING

S. V. Yakhin* ORCID 0000-0002-0042-0844
O. A. Burlaka ORCID 0000-0002-2296-7234

Poltava State Agrarian Academy, 1/3, Skovorody Str., Poltava, 36003, Ukraine
*Corresponding author
E-mail: sergii.iakhin@pdaa.edu.ua

How to Cite

Yakhin, S. V., & Burlaka, O. A. (2020). Research on the influence of the operating modes of combine harvester's transportation lines on the quality of grain threshing. Bulletin of Poltava State Agrarian Academy, (3), 269–279. doi: 10.31210/visnyk2020.03.31

The aim of the study is to develop recommendations for reducing grain losses based on the analysis of experimental data on the characteristics of flows during its transportation by the scraper elevators of a combine harvester. Primary experimental data were obtained using capacitive-wave sensors for grain threshing. For carrying out experimental studies, a combine harvester KZS-9-1 "Slavutych" was chosen, which was equipped with a grain threshing sensor DNZ-01. To control the productivity of the grain-bearing elevators, it was equipped with a grain re-threshing sensor DDZ-01. An on-board computer was used to record data on the productivity of the grain flow of the elevator. The grain threshing sensor and the grain re-threshing sensor according to the functional diagram are made in the same way but differ in geometric parameters. This is due to the design features of the grain transport lines of the combine, and is considered as the main part of the experimental equipment for controlling the flow of agricultural materials. The measurement results were processed using the methods of mathematical and statistical analysis using applied computer programs. The performance of the grain and spike elevator of the KZS-9-1 "Slavutych" combine was measured in the field using sensors for threshing and final threshing of grain when harvesting winter wheat by direct combining with an average yield of 4.8 t/ha, grain moisture – 12…13%, straw content – 1 : 1 and the upright vegetation cover of grain fields. The site was chosen as a strip of a field with a width of 14 m and a length of 1000 m, had clogged areas and liquefied crops, that is, the real working conditions of the combine. When comparing the experimental flow characteristics of the productivity of the grain and grain elevators of the combine with the well-known parameters of the quality of technological adjustments of the thresher, at the initial stage, free grain in the final threshing line was found. At the same time, the average productivity of grain transportation in the threshing line was 3…4 kg/s, in the final grinding line – 0.05…0.15 kg/s. By changing the technological adjustments of the thresher, no possible flow of the grain heap in the final threshing line was achieved – 0.04…0.08 kg/s, which increased the productivity of transporting grain to the bunker to 3.1…4.2 kg/s. Such correction of the technological process made it possible to reduce the level of grain losses (according to the indicator of the serial control system on 7…15% by reduce the intensity of losses), which is especially effective in areas infested with weeds.

***Key words**: grain harvester, grains, threshing, elevator, productivity, grain threshing sensor, grain final threshing sensor, winter wheat.*

ДОСЛІДЖЕННЯ ВПЛИВУ РЕЖИМІВ РОБОТИ ТРАНСПОРТНИХ ЛІНІЙ ЗЕРНОЗБИРАЛЬНОГО КОМБАЙНА НА ЯКІСТЬ ОБМОЛОТУ ЗЕРНА

С. В. Яхін, О. А. Бурлака
Полтавська державна аграрна академія, м. Полтава, Україна

Метою дослідження є розробка рекомендацій щодо зменшення втрат зерна на основі аналізу експериментальних даних характеристик потоків при його транспортуванні скребковими елеваторами зернозбирального комбайну. Первинні експериментальні дані отримані за допомогою ємнісне-хвильових датчиків намолоту зерна. Для проведення експериментальних досліджень обрано зернозбиральний комбайн КЗС-9-1 «Славутич», обладнаний датчиком намолота зерна ДНЗ-01. Для контролю продуктивності колосового елеватора його було обладнано датчиком домолоту зерна ДДЗ-01. Фіксацію даних щодо продуктивності зернового потоку елеватора здійснював бортовий комп'ютер типу «MONOMAC». Датчик намолоту зерна та датчик домолоту зерна по функціональній схемі виконані однаково, але розрізняються геометричними параметрами Це зумовлено особливостями конструкцій зернових транспортних ліній комбайна та розглядаються, як основна частина експериментального обладнання для контролю потоків сільськогосподарських матеріалів. Результати вимірювань були опрацьовані за допомогою методів математичного та статистичного аналізу з використанням прикладних комп'ютерних програм. Продуктивність роботи зернового та колосового елеваторів комбайна КЗС-9-1 «Славутич» вимірювалась у польових умовах за умови допомогою датчиків намолоту та домолоту зерна при збиранні озимої пшениці прямим комбайнуванням за середньої врожайності 4,8 т/га, вологості зерна – 12…13%, соломистості – 1 : 1 та прямостоячому хлібостої. Обрана ділянка – смуга поля шириною 14 м та довжиною 1000 м, яка мала забур'янені зони та зріджені посіви, тобто реальні виробничі умови роботи комбайна. При зіставленні експериментальних потокових характеристик продуктивності зернового та колосового елеваторів комбайна із загальновідомими параметрами якості технологічних регулювань молотарки було виявлено на початковому етапі вільне зерно в лінії домолоту. Водночас середня продуктивність транспортування зерна в лінії намолоту склала 3…4 кг/с, в лінії домолоту – 0,05…0,15 кг/с. Зміною технологічних регулювань молотарки досягнуто найменшого можливого потоку зернового вороху в лінії домолоту – 0,04…0,08 кг/с, що підвищило продуктивність транспортування зерна в бункер до 3,1…4,2 кг/с. Така корекція технологічного процесу дала змогу зменшити рівень втрат зерна (за індикатором серійної системи контролю на 7…15 % за зменшенням інтенсивності втрат), що особливо ефективно на засмічених бур'янами площах.

***Ключові слова**: зернозбиральний комбайн, втрати зерна, обмолот, елеватор, продуктивність, датчик намолоту зерна, датчик домолоту зерна, озима пшениця.*

ИССЛЕДОВАНИЕ ВЛИЯНИЯ РЕЖИМОВ РАБОТЫ ТРАНСПОРТНЫХ ЛИНИЙ ЗЕРНОУБОРОЧНЫХ КОМБАЙНОВ НА КАЧЕСТВО ОБМОЛОТА ЗЕРНА

С. В. Яхин, А. А. Бурлака
Полтавская государственная аграрная академия, г. Полтава, Украина

Целью исследования является разработка рекомендаций по уменьшению потерь зерна на основе анализа экспериментальных данных характеристик потоков при его транспортировке скребковыми элеваторами зерноуборочного комбайна. Первичные экспериментальные данные получены с помощью емкостно-волновых датчиков намолота зерна. Производительность работы зернового и колосового элеваторов комбайна КЗС-9-1 «Славутич» измерялась в реальных производственных условиях работы комбайна. Изменением технологических регулировок молотилки достигнуто наименьшего возможного потока зернового вороха в линии домолота – 0,04…0,08 кг/с, что повысило производительность транспортировки зерна в бункер до 3,1…4,2 кг/с. Такая коррекция технологического процесса позволила снизить уровень потерь зерна (по индикатору серийной системы контроля на 7…15 % по убыванию интенсивности потерь), что особенно эффективно на засоренных сорняками площадях.

***Ключевые слова**: зерноуборочный комбайн, потери зерна, обмолот, элеватор, производительность, датчик намолота зерна, датчик домолота зерна, озимая пшеница.*

Introduction

The branch of crop production is the dominating component of food security of Ukraine, and Poltava region has a significant level of production, processing, and sales of grain and leguminous crops.

Critical indicators of grain production quality include environmental friendliness and energy-saving technologies. Elements of engineering innovations in crop production are also directed to reducing the harvesting losses.

Harvesting grain is the final step in the crop production process. The dominating element of the assembly complex of farm vehicles is the combine harvesters [1, 2, 3]. The thrashing of grain and leguminous crops is the last stage of that technology and therefore requires special attention. Unfortunately, nowadays, one can quite often observe situations when after the cleaning of early grain crops, the field plentifully turns green in the fall because of the loss of grain caused by the violation of production technologies. Therefore, the subject of the chosen direction of the research is relevant and has practical value.

There are several works of the famous Ukrainian and foreign scientists, devoted to theoretical and practical solutions, that can improve the use of combine harvesters by reducing the losses of grain and enhancing the quality of thrashing: L. V. Pohorilyi, V. A. Sakun, V. O. Sheychenko, O. M. Pohoril′tsiya, A. A. Demko, M. D. Zenko, M. K. Liny, V. I. Nedovesov, etc. In their works, the theoretical, technological, and experimental components of technical operations of thrashing the grain are thoroughly stated [6, 9, 10, 12, 13, 15, and 20].

Papers, devoted to finding the abstract patterns and development of scientific hypotheses of the studied subject, are [1, 6, 12, 13]. These scientific researches describe the modelling of technological processes of thrashing, separating, and passing grain streams to combines.

A number of publications are devoted to the technique, methodology, and processing the results of pilot studies on improvements in designs and increasing the productivity of combines on thrashing of various grain, leguminous and commercial crops [7, 9, 10, 15, 16, 20].

Assessment of the quality of modern combines on the thrashing of grain crops is a complex multi-criteria problem of current agricultural production. In that direction, thorough probes are stated in the works of famous scientists [14, 16, 17, and 18].

The author of several publications [4, 5, 7, 8, 10, and 19] considered another criterion for evaluating the technological level and the strategy of improving the design of grain-harvesting complexes. Those papers also provide improvement options for the technical support of grain thrashing operational technology, which includes the use of modern systems of automatic check and adjustment.

Besides, the adaptability of the current grain thrashing technologies of both Ukraine, comparing to the other countries, as well as the features of collecting non-grain parts, are described by the famous scientists V. A. Sheychenko, V. I. Nedovesov, V. A. Dubrovin, etc. [12, 13, 18, 19].

However, the majority of studies do not pay sufficient attention to the effects of climate change, which causes speedup in the variability of agro-technical conditions of cleaning the grain crops. The climate on the planet grows warm. The problem of insufficient moistening in crop production becomes more relevant.

The problems of the scientific direction devoted to questions of commodity assembly quality and grain seed combines are stated in several papers in the international editions [21–24, 26–28]. The results of such works focus on the interaction of working mechanisms of threshing-separating devices and grain mass. The techniques and methodologies of scientific experiments, devoted to the influence patterns of the thrashing system design data on such important indicators of quality as bunker grain contamination, crushing, compression and abrasive grain damages, deterioration in similarity, specific power parameters of assembly complex are described.

But the questions stated above require further improvement and more in-depth research. Thus, the subject of this branch of scientific research is relevant, and the increased demand in the operating conditions of combine harvesters, demand constant improvement, adaptation of their design to constantly changing agro-ecological conditions of the corresponding agricultural region.

The purpose of this scientific publication is to obtain data on quantity characteristics of grain stream that is transported by a scraper elevator of the combine harvester**,** using specific sensors. The analysis of the experimental research results may reveal the underlying cause of grain loss and provide a method to reduce them.

The task of research:

1. To propose a method of pilot studying and testing the performance of the grain transportation control units of the elevators of KZS-9-1 “Slavutych” combine harvester as an example.
2. Conduct pilot studies to define and compare the stream performance characteristics of a grain elevator

and a cereal elevator of the final threshing line of the combine harvester in cleaning the winter wheat on condition of grain loss minimization.

3. Prove the expediency of controlling the performance of grain and cereal elevators of the combine harvester in transporting grain as a new method of controlling the optimal operating parameters of the thresher and minimizing the harvest loss.

Materials and methods of research

By applying the developed capacitive sensor to a threshed grain to obtain primary experimental data on the characteristics of the technological mode of transporting the grain by the grain elevator of KZS-9-1 "Slavutych" combine harvester. The results of measurements are processed using the methods of the mathematical and statistical analysis and the specialized computer programs.

Results of research and their discussion

For the majority of modern combine harvesters, scraper elevators (fig. 1, poses 3) are an integral part of the grain transport group, which are used to bring the grain up into the bunker. For transportation of non-threshed grain in the final threshing device, the inclined elevator is used instead (fig. 1, pos. 5).

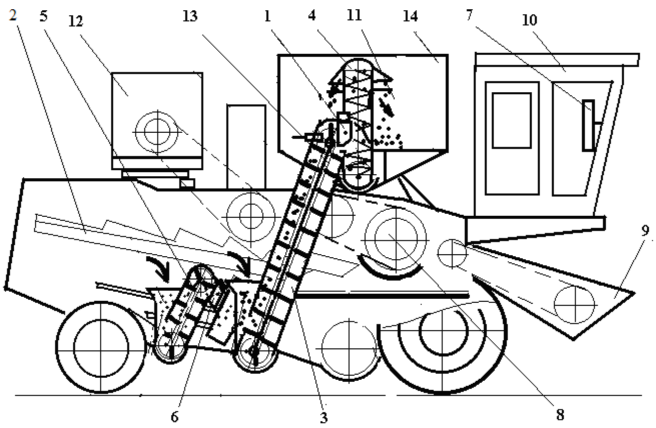

Fig. 1 The scheme of additional equipment of the KZS-9.1 "Slavutych" combine harvester for research of grain streams

1 – sensor to grain yield of kernels; 2 – straw shaker; 3 – grain elevator; 4 – the loading screw of bunker 5 – ear elevator; 6 – sensor of the final threshing of grain; 7 – on-board computer; 8 – thresher; 9 – inclined chamber; 10 – cabin; 11 – zone of unloading of grain in the bunker; 12 – motor power plant; 13 – the sensor of the turnovers control; 14 – grain bunker.

The KZS-9-1 "Slavutych" combine harvester has been chosen as a base for carrying out pilot studies. To control the performance of its grain elevator, the combine has been specially equipped with the sensor of the thrashing of DNZ-01 grain (fig. 1, pos. 1). For additional control of the elevator performance, the sensor of the final threshing of DDZ-01 grain has also been equipped by the ear elevator (fig. 1, pos. 6) with the special onboard computer (fig. 1, pos. 7).

Such technical solution has allowed us to measure the most precise characteristics of the grain stream in the control zone during the harvesting operation of the combine.

Sensors of grain thrashing and the final threshing, according to the function chart, are operating equally (fig. 2) [5]. They differ in geometrical parameters that depend on the design of the combine's grain transportation lines and are considered as the central part of the device for controlling the streams of agricultural materials [5]. The device consists of two capacitive sensors and a microcomputer for processing the output signal from sensors.

The high-frequency sensor (fig. 2) has three electrodes 14 (with the purpose of creating the zone of control), the generator of electromagnetic oscillations 7 has the first-mentioned electrode as an output, a control zone 13 shielding device, amplifier 10 connected to the network of the negative feedback coupling which has an input connected to the second electrode mentioned above. Detector 18 input is connected to the output of the amplifier 10 and also the output block of making the signals 9. Electrodes are constructed as the open conducting surfaces isolated by dielectric layer pads, used to shield the zone of control on faces and from the side, opposite to the area of control [5].

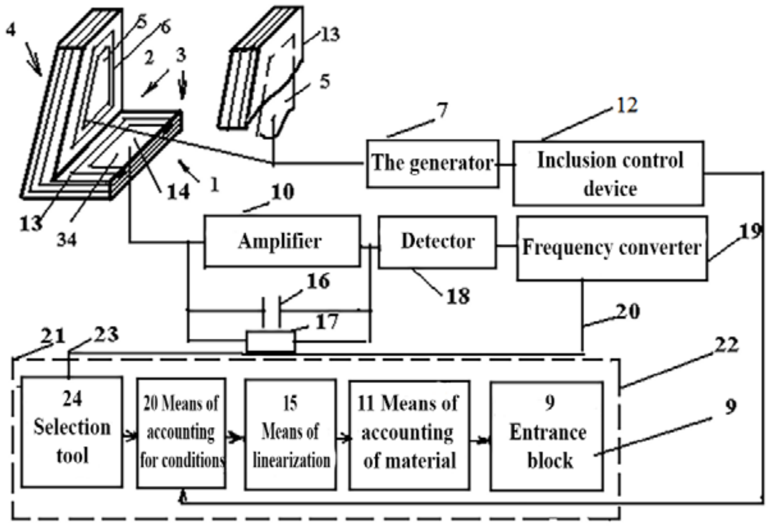

Fig. 2 The function chart of the device for controlling quantity characteristics of grain streams

1 – sensor base; 2, 3 – the direction which forms control zone; 4 – side part of the sensor; 5 – electrode; 6 – the insulator; 7 – the generator; 8 – electronic block of the sensor; 9 – entrance block; 10 – amplifier; 11 – means of accounting of material; 12 – inclusion control device; 13 – screen; 14 – electrode; 15 – means of linearization; 16 – the condenser; 17 – the resistor; 18 – detector; 19 – frequency converter; 20 – means of accounting for conditions

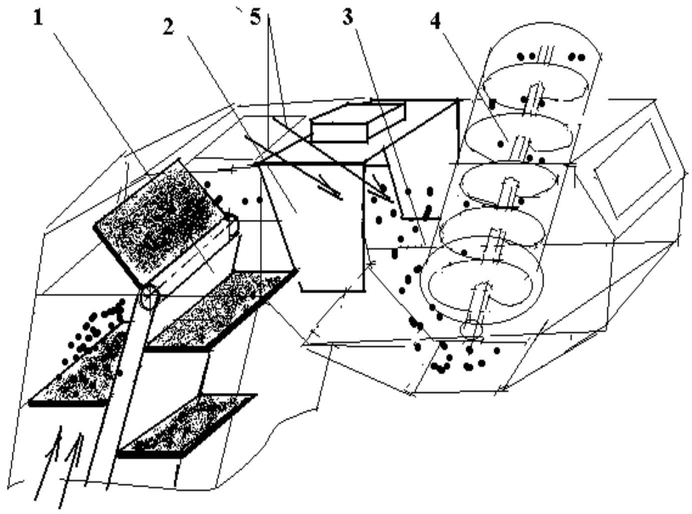

Fig. 3 Placement of the Sensor of grain kernels yield in the reloading cell of the KZS-9-1 "Slavutych" combine harvester

1 – grain elevator; 2 – sensor to grain yield of kernels; 3 – reloading camera; 4 – the loading screw of bunker 5 – grain flow direction (elements of casings are conditionally shown transparent)

The benefits of installing the sensor of yielding the grain kernels in the reloading chamber formed at the exit of the upper part of grain elevator (fig. 3, pos. 2) and the similar scheme of installing the sensor of the grain final threshing, are that between lifting elevator and the loading screw of the bunker there are no transport devices or working bodies so that we can use sensors of high-frequency or capacitive type for measurements.

The choice of mechanical parameters of sensors of kernels yielding and the grain final threshing is proved by the strength calculations of their bearing part and also the technological expediency of sensors production. Therefore, the accepted material to produce the body, the screen, and the electrodes is steel sheet, 2 mm thick.

The design of sensors of yielding the kernels of grain and the sensor of the final threshing of grain developed by us are presented in the form of design-layout schemes in fig. 4 and fig. 5 for use option in the KZS-9-1 “Slavutych” combine harvester.

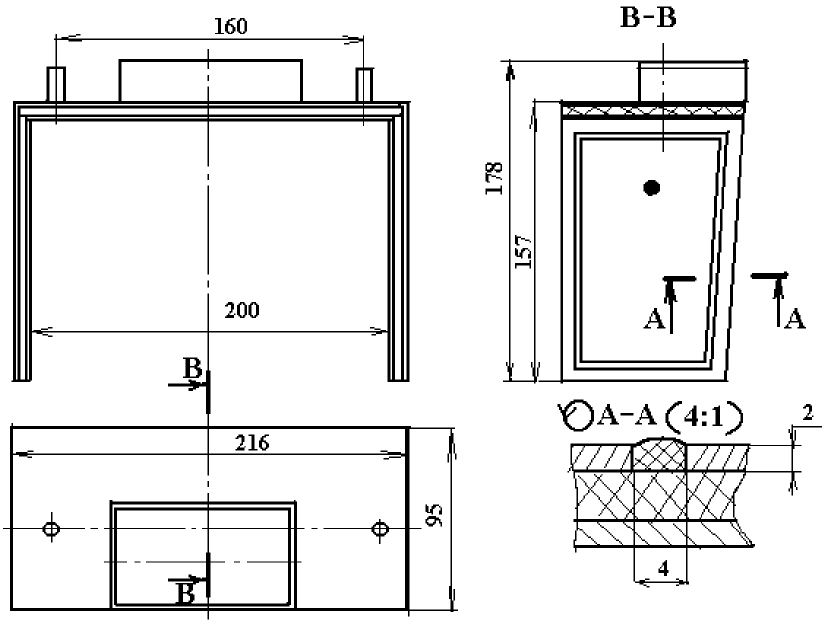

Fig. 4 Design-layout scheme DNZ-01

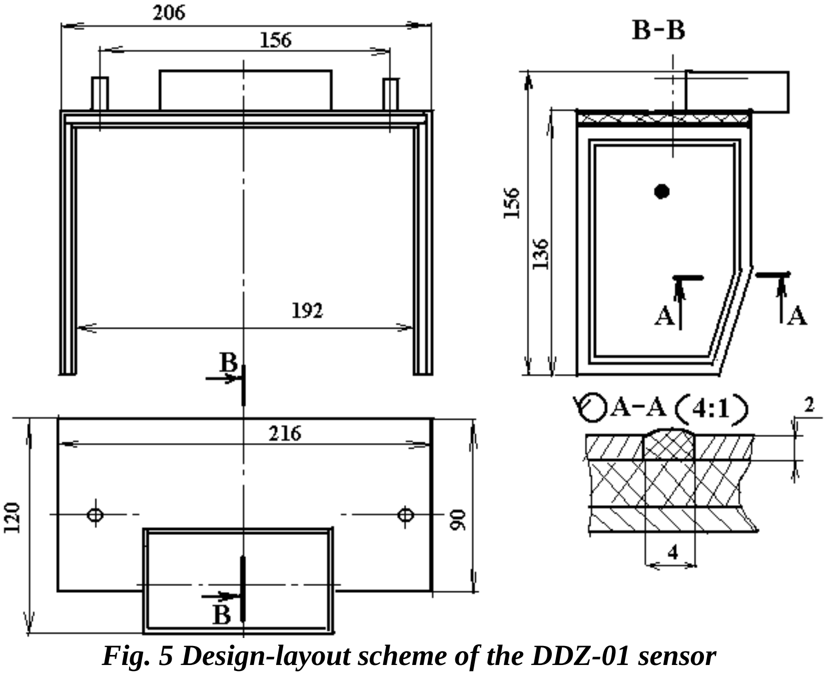

Fig. 5 Design-layout scheme of the DDZ-01 sensor

During the sensor designing process, a vital task of determining the geometrical parameters of the lateral section of chase under the isolating element was also solved (fig. 4, fig. 5). Based on the electrical requirements on the functioning of the isolating elements of the designed device, the lateral section of the chase sizes of 2×4 mm has been chosen. The general plane and configuration of electrode plates are designed to provide a more uniform electromagnetic field in the control zone.

To determine the calibration coefficients for recalculating the display of elevator performance in grain streams by the on-board computer, to control the intervals of time was the purpose of the first part of probes on the described technique. Calibrating operations of the designed equipment, which transport technological processes features of grain streams in the combine are studied, were carried out as follows. The combine worked without moving across the field. At the same time, all working bodies, to reproduce the vibration influences, which always take place during the operation of machines of this type, have been put into action. The main thing in organizing these measurements is to create an artificial passage through the transport and grain group of the thresher of the consistent on performance and equal on intensity grain stream, for various crops collected by the combine.

When carrying out those researches, the performance of transporting the grain, contaminated with plants, has to be controlled by the elevator or known in advance. This condition has been satisfied directly at the first weight measurement of grain stream at the exit from the loading screw of the combine bunker (fig. 3, pos. 4), while for the final threshing elevator - after preliminary calibrating of the gates, which has been mounted on the loading container in the sensor zone (fig. 3, pos. 6). The application of such decision has allowed to change grain expenses on time range from zero to the nominal loading time of the elevator with a performance of 5 kg/s, which is necessary for calibration operations.

The nominal operating mode of the thresher was also artificially set using the additional equipment to avoid the influence on the reflection of a grain stream variation of the transportation speed when carrying out calibration operations.

With such working conditions, an unevenness of material intake, that arises from the existence of a real unevenness of loading extent of the thresher of the combine harvester during its work has also been excluded. Carrying out the experiments in such conditions has allowed us to receive an exact calibration of the measuring equipment and to study the factors affecting the nature of reflection of grain stream in a zone of control of the sensors of kernels yielding and the final threshing in detail.

After carrying out operations of calibrating, the performance of work of grain and ear elevator of the KZS-9-1 “Slavutych” combine was studied using the sensors of kernels yielding and the final threshing of grain in the field conditions. Harvesting winter wheat was carried out by direct combining at an average yield of 4.8 t/ha at moistness of grain – 12…13 %, straw content – 1 : 1 and upright stand of grain. The site of the size of a field strip, 14 m wide and 1000 m long, and with contaminated zones and the liquefied crops that corresponds to real operating conditions of the combine has been chosen.

The degree of grain contamination changed at the expense of the directed variation of thresher technological regulation. To obtain grain mass of the highest possible purity the following adjusting parameters have been set: an increased threshing drum momentum for the gathered crops; the gap between the threshing drum and the combine concave is nominal; the speed of the cleaning fan airflow is increased; gaps between combs of upper sieve and the extender of the upper sieve are nominal; gaps between combs of the lower sieve are reduced. It should be noted that to prepare the experimental combine harvester for cleaning, the additional sieves have been installed. As a result, the quality of separation has improved due to the eliminated influence of unevenness of the extent of the openings of the sieve that arises in the course of their operating. And in need of an increase in contamination of grain stream, the respective changes in technological adjustments of the thresher were applied: a momentum of threshing drum is increased, the nominal gap between the drum and the combine concave is set, gaps size on cleaning sieves is increased, the intensity of airflow of the cleaning fan is reduced. Change of losses of grain when performing a series of these experiments was not taken into consideration.

Measures to eliminate grain bunker contamination were carried out by well-known methods by means of weighing and comparison of control samples. Range of variation of contamination has been determined according to agro-technical requirements to the degree of purity of bunker grain within range from 1 to 4 percent. Certain difficulties arose when studying the influence of moistness on the reflection of the grain stream. Therefore, moistness of grain has been limited to agro-technical requirements (not more than 14 %), and its influence was studied with various collecting’s the same culture and was considered further by the correction factor. The time of one measurement is set by 3 pages. Results of primary performance measurements are presented in the form of stream characteristics (fig. 6 and fig. 7).

The results of pilot studies show, that by comparing the stream characteristics of the performance of a grain elevator (fig. 6) and ear elevator (fig. 7) of the final threshing line of the combine on field tests with the general methods of quality control of technological adjustments of the thresher free grain has been found at the initial stage in the line of the final threshing. At the same time the average performance of transporting the grain in the line of kernels yielding was 3…4 kg/s, and in the line of the final threshing - 0.05…0.15 kg/s.

Change of technological adjustments of the thresher have reached the smallest possible stream of the line of the final threshing – 0.04…0.08 kg/s (fig. 9) that has increased the performance of transportation of grain in the bunker to 3.1…4.2 kg/s (fig. 8).

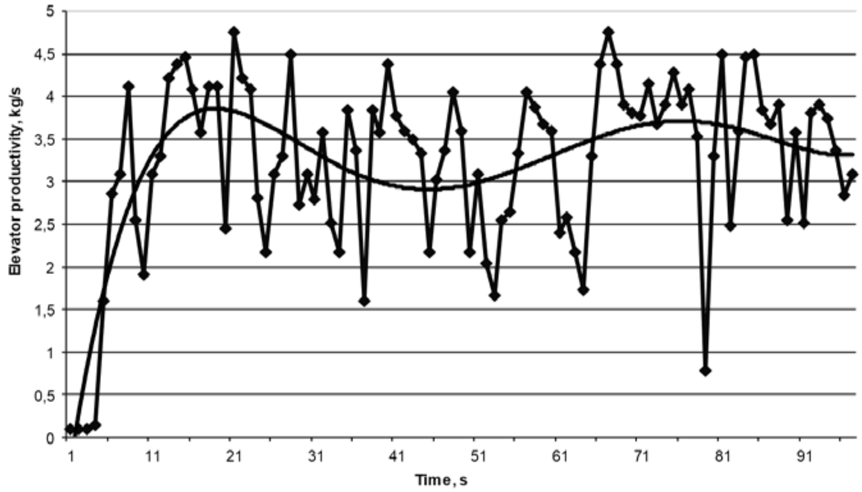

Fig. 6 Graph of productivity change at the outlet of the scraper grain elevator before adjustment

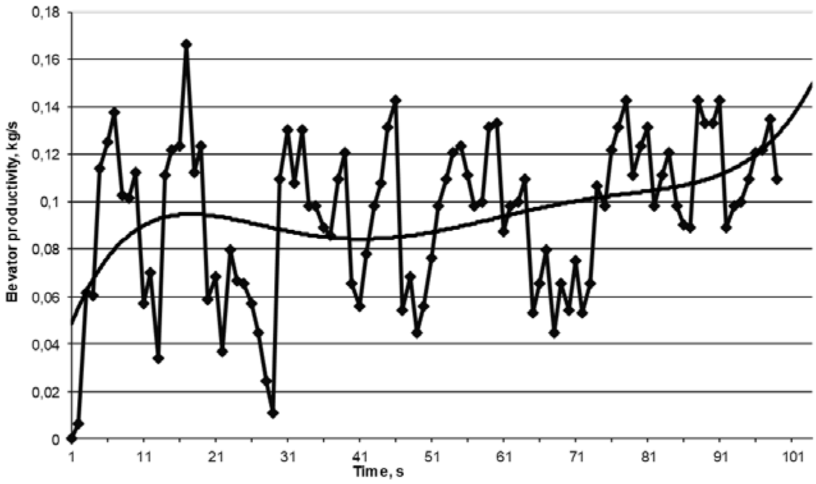

Fig. 7 Graph of changing productivity of the final threshing line, at the exit from the scraper elevator before adjustment

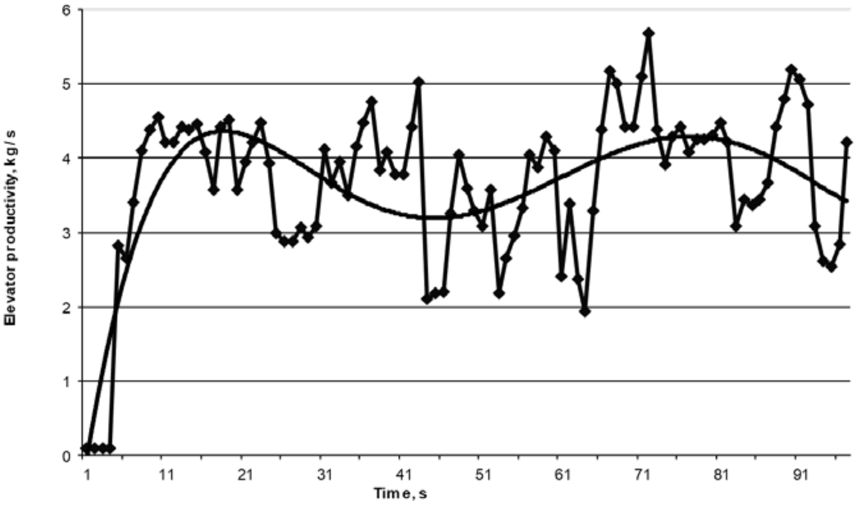

Fig. 8 Graph of productivity change at the outlet of the scraper grain elevator after adjustments

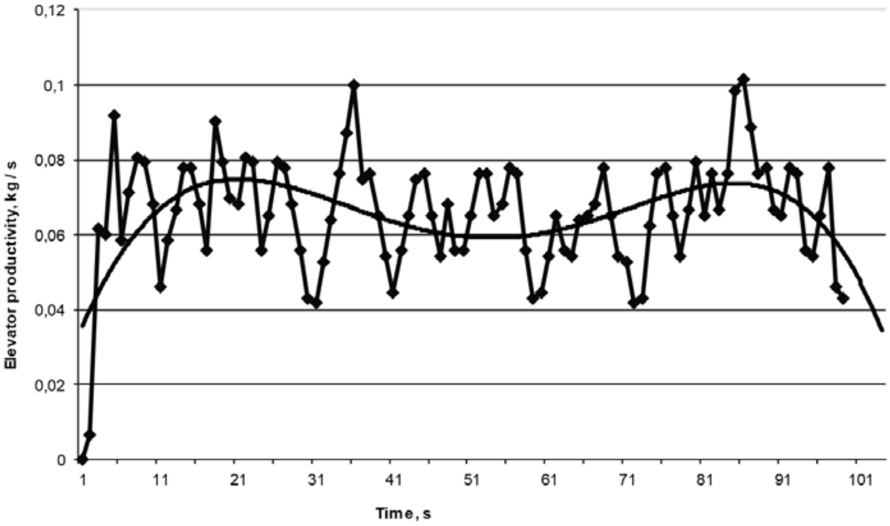

Fig. 9 Graph of changing the productivity of the final threshing line, at the exit from the scraper elevator after adjustments

Such correction of the technological process has allowed to reduce the loss rate of grain (according to the indicator of the serial control system on 7…15 % by reducing the intensity of losses) that is especially effective for the areas which are contaminated with weeds.

The deviation from standard operating of the measuring equipment has been recorded when clogging the sensors zone of control by the technological remains of crops or the earth as well. This phenomenon was especially noticeable under the conditions of cleaning. The influence of those negative factors has been calculated by the additional on-board computer as a significant change in the initial condition of calculations for the transportation of grain. The revealed defects have been eliminated due to the reduction of local resistance from the experimental sample of the grain kernels yielding sensor and also the correction of technological adjustments of the thresher for the purpose of reducing the contamination of grain stream. The analysis of the phenomenon described above have been considered for further improvement to the kernels yielding sensor for the KZS-9-1 “Slavutych” combine harvester and creation of the general operational program of automatic check and control of the loading of grain-harvesting machines.

Conclusions

1. By the results of the pilot studies the following results are obtained: by comparing the stream performance of grain elevator to the grains elevator of the final threshing line of the combine in cleaning the winter wheat with the general methods of quality control of the thresher technological adjustments, free grain has been found at the initial stage of the final threshing line. At the same time, the average performance of grain transportation to the kernel yielding line was 3…4 kg/s, and for the line of the final threshing – 0.05…0.15 kg/s.

2. By adjusting the thresher, we achieved a speed of the stream in the final threshing line of 0.04…0.08 kg/s for the KZS-9-1 “Slavutych” combine harvester, which has also increased the performance in transporting the grain into the bunker to 3.1…4.2 kg/s). Such correction of technological process has allowed us to reduce the loss rate of grain (on the indicator of serial control system BK-01 by a 7 to 15 % decrease of losses intensity) that is especially effective on the areas, which are contaminated with weeds.

3. The analysis of the performance curves of the grain stream created by the scraper elevators of the combine in yielding the kernels and the final threshing of grain, given in our probes, demonstrates that the designed equipment is capable of controlling and reproducing the quantity characteristics of streams, namely – the grain transportation performance of the scraper elevators of the combine. There is possible determination of parameters of technological process of grain thrashing for the combine, such as the time of loading the thresher to the nominal mode of thrashing, features of transition processes; general unevenness of a grain stream; reduction in the rate of transportation, clogging of the reloading chamber in the control zone; definition of the beginning of emergency operation.

4. The deviation from standard duties of the measuring equipment operation has been recorded when

clogging the sensors zone of control by the technological remains of crops or the earth. Such phenomenon was especially observed under the cleaning conditions. Influence of such negative factor has been calculated by the additional on-board computer as a significant change in the initial conditions of transporting the grain. The revealed defects have been eliminated due to the reduction in local resistance from the experimental sample of the kernels-yielding sensor and corrections of operating parameters of the thresher for the purpose of lowering the contamination of grain stream. The analysis of the phenomenon described above has been considered for further improvement of the kernels yielding sensor the for the KZS-9-1 “Slavutych” combine harvester and developing the general operational program of automatic check and control of loading of grain-harvesting machines.

5. The equipment of scraper elevators of the KZS-9-1 “Slavutych” combine harvester with the sensors of kernels yielding, the final threshing of grain and the additional on-board computer, allows us to investigate operating modes of transportation lines by displaying the quantity characteristics of grain streams. At the same time, it is possible to study technological features of grain transportation and the impact of those changes on the operational process of the combine and to improve the quality of the thresher operations by reducing the losses of grain.

Prospects of further probes. Based on this research, it turns out, that such technological solutions can be reasonable to be used on such combine harvesters produced in Ukraine as “Slavutych” and “Skif” for further improving of their operational modes and the design of thresher-separating system.

References

1. Burlaka, O. A., & Yahin, S. V. (2018). Pidvishennya efektivnosti roboti skrebkovih elevatoriv z vidcentrovim tipom rozvantazhennya. *Visnik Poltavskoyi Derzhavnoyi Agrarnoyi Akademiyi*, (4), 195–200. doi: 10.31210/visnyk2018.04.31. [In Ukrainian].
2. Burlaka, O. A., Yahin, S. V., & Dudnik, V. V. (2019). Eksperimentalni doslidzhennya procesu transportuvannya zerna elevatorom zernozbiralnogo kombajnu. *Visnik Poltavskoyi Derzhavnoyi Agrarnoyi Akademiyi*, (1), 232–240. doi:10.31210/visnyk2019.01.28. [In Ukrainian].
3. Burlaka, O. A., Yahin, S. V., & Drozhchana, O. U. (2019). Doslidzhennya vplivu solomistosti ta stupenya zavantazhennya molotarki zernozbiralnih kombajniv ACROS-530 ta «JD-9500» na yakist obmolotu zerna ozimoyi pshenici. *Visnik Poltavskoyi Derzhavnoyi Agrarnoyi Akademiyi*, (2), 293–303. doi: 10.31210/visnyk2019.02.38. [In Ukrainian].
4. Derevyanko, D. A. (2014) Vpliv nadhodzhennya hlibnoyi masi v molotilnij aparat pid chas obmolochuvannya na travmuvannya nasinnya. *Visnik Agrarnoyi Nauki*, 8, 53–56 [In Ukrainian].
5. Kirkhberher, F., Sakalo, M. H., & Sakalo, L. H. (1994). *Patent Ukrainy № 1389.* Kyiv:Ukrayinskij institut intelektualnoyi vlasnosti [In Ukrainian].
6. Zenko, M. D., & Nyedovyesov, V. I. (2013) Analitichne modelyuvannya vtrat zerna za molotarkoyu v zalezhnosti vid umov roboti zernozbiralnogo kombajna. *Mehanizaciya i Elektrifikaciya Silskogo Gospodarstva*, 97 (1), 483–488 [In Ukrainian].
7. Kravchuk, V., & Zanko, M. (2013) Doslidzhennya vtrat zerna za molotarkoyu zernozbiralnogo kombajna. *Tehnika i Tehnologiyi APK*, 5, 8–12 [In Ukrainian]
8. Kushnaryov, A. Kravchuk, V., & Lezhenkin A. (2010) Problemy sovershenstvovaniya tehno-logii uborki zernovyh. *Tehnika i Tehnologiyi APK*, 2, 6–12 [In Russian].
9. Linnik, M. K., Sirenko, V. F., & Zhabko, A. I. (2013) Eksperimentalni doslidzhennya vtrat nasinnya ripaku pri zbiranni zernozbiralnimi kombajnami pryamim kombajnuvannyam posiviv. *Silskogospodarski Mashini*, 24, 201–209 [In Ukrainian].
10. Samigullin, D. K., Hafizov, R. N., Tuhvatullin, A. A., & Hafizov, K. A. (2012) Metodika i rezultaty eksperimentalnyh issledovanij poter zerna na uborke. *Hranenie i Pererabotka Zerna*, 2, 17–20 [In Russian].
11. Samigullin, D. K., Hafizov, R. N., Tuhvatullin, A. A., & Hafizov, K. A. (2012) Metodika i rezultaty eksperimentalnyh issledovanij poter zerna pri uborke. *Hranenie i Pererabotka Zerna*, 2, 17–20 [In Russian].
12. Nyedovyesov, V. I., & Zanko, M. D. (2012) Grafichne i matematichne modelyuvannya pokaznika «Ob’yem bunkera zernozbiralnogo kombajna». *Mehanizaciya i Elektrifikaciya Silskogo Gospodarstva*, 96, 240–246 [In Ukrainian].
13. Sheychenko, V. O., Anelyak, M. M., & Tolstushko, M. M. (2013) Obgruntuvannya se paruyuchoyi poverhni reshit zernozbiralnih kombajniv. Silskogospodarski mashini, 26, 151–156 [In Ukrainian].
14. Rozhanskij, O., Harenko, M., Kremsal, V., & Lisak, O. (2010) Ocinka yakosti roboti zernozbiralnih

kombajniv u gospodarstvah Ukrayini. *Tehnika i Tehnologiyi APK*, 5, 28–31 [In Ukrainian].

15. Pogorilij, L., Ivasyuk, V., & Solomaha, O. (2002) Do praktichnoyi realizaciyi monitoringu gruntiv u sistemi tochnogo zemlerobstva. *Tehnika i Tehnologiyi APK*, 10-11, 8–9 [In Ukrainian].

16. Smolinskij, S. V. (2016) Metodologichni principi ocinki efektivnosti roboti zernozbiralnih kombajniv. *Visnik Harkivskogo Nacionalnogo Tehnichnogo Universitetu Silskogo Gospodarstva imeni Petra Vasilenka*, 170, 134–137 [In Russian].

17. Smolinskij, S. V., & Mironenko, V. G. (2012) Robochij proces zernozbiralnogo kombajna yak ob'yekt adaptaciyi. *Zbirnik Naukovih Prac Vinnickogo Nacionalnogo Agrarnogo Universitetu*, 11 (2), 265–269 [In Ukrainian].

18. Dubrovin, V. O., Demko, A. A., Nadtochij, O. V., & Demko, O. A. (2012) Tehniko-ekonomichna ocinka rivnya suchasnih zernozbiralnih kombajniv. *Naukovij Visnik Nacionalnogo Universitetu Bioresursiv i Prirodokoristuvannya Ukrayini*, 170 (1), 51–60 [In Ukrainian].

19. Sheychenko, V., Anelyak, M., & Kuzmich, A. (2016) Gnuchke zbirannya. *The Ukrainian Farmer*, 11, 122–124 [In Ukrainian].

20. Sheychenko, V., Anelyak, M., & Kuzmich, A. (2016) Vyzov prinyat! Kak umenshit sebestoimost uborki zernovyh kultur sovremennymi kombajnami. *Zerno*, 4, 114–116 [In Russian].

21. Choi, M.-C., Lee, K.-H., Jang, B.-E., Kim, Y.-J., & Chung, S.-O. (2018). Grain flow rate sensing for a 55 kW full-feed type multi-purpose combine. *International Journal of Agricultural and Biological Engineering*, 11 (5), 206–210. doi: 10.25165/j.ijabe.20181105.2686.

22. Douglas E. Fiscus, & George H. Foster and Henry H. Kaufmami. (1971). Physical Damage of Grain Caused by Various Handling Techniques. *Transactions of the ASAE*, 14 (3), 0480–0485. doi: 10.13031/2013.38319.

23. ISTA Documents, (2011). International Rules for Seed Testing, International Seed Testing Association. Bassersdorf/Switzerland.

24. Menezes, P. C. de, Silva, R. P. da, Carneiro, F. M., Girio, L. A. da S., Oliveira, M. F. de, & Voltarelli, M. A. (2018). Can combine headers and travel speeds affect the quality of soybean harvesting operations? *Revista Brasileira de Engenharia Agrícola e Ambiental*, 22 (10), 732–738. doi: 10.1590/1807-1929/agriambi.v22n10p732-738.

25. Shahbazi, F., Valizadeh, S., & Dowlatshah, A., (2012), Mechanical damage to wheat and triticale seeds related to moisture content and impact energy. *Agricultural Engineering International: CIGR Journal*, 14 (4), 150–155.

26. Sheychenko, V. O., Kuzmych, A. Ya., Shevchuk, M. V., Shevchuk, V. V., & Belovod, O. I. (2019) Research of quality indicators of wheat seeds separated by prethreshing device. *INMATEH – Agricultural Engineering*, 57 (1),157–164.

27. Shpokas, L., Adamchuk, V., Bulgakov, V., & Nozdrovicky, L., (2016), The experimental research of combine harvesters. *Research in Agricultural Engineering*, 62, 106–112.

28. Zielinski, A., & Mos, M., (2009). Effects of seed moisture and the rotary speed of a drum on the germination and vigour of naked and husked oat cultivars. *Cereal Research Communications*, 37 (2), 277–286.

Стаття надійшла до редакції 25.07.2020 р.

Бібліографічний опис для цитування:

Яхін С. В., Бурлака О. А. Дослідження впливу режимів роботи транспортних ліній зернозбирального комбайна на якість обмолоту зерна. *Вісник ПДАА*. 2020. № 3. С. 269–279.