Increase in grain combine harvester performance and in quality of harvesting grain crops

G G Maslov, E M Yudina* and N A Rinas

Federal State Budgetary Educational Institution of Higher Education “Kuban State Agrarian University named after I.T. Trubilin”, 13, Kalinina st., Krasnodar, 350044, Russia

* E-mail: elena_yudina1963@mail.ru

Abstract. Based on the analysis of the results of combine harvester production tests and the long-term studies, carried out by the authors, the directions for increase in combine harvester productivity and in grain crop harvesting quality, are proposed. In three blocks of directions for increasing the combine harvester efficiency, a new direction of completing multifunctional harvesting units, joining together grain harvesting with simultaneous performance of one of the accompanying operations (stubble plowing, straw pressing, sowing catch crops, etc.), is found. The acquisition of multifunctional harvesting units is based on self-propelled, all-wheel-drive harvesters, trailed and mounted on a power unit such as “Palesse” (Belarus). The original unit can be completed on the basis of a “Penha” pull-type combine (Brazil). Among other directions of combine efficiency increasing, the observance of the rhythm and flow of the working process is substantiated, the attention is paid to the complex performance of the harvesting period. Attention is also paid to the obligatory coordination of the relationship between combine parameters and harvesting conditions: field size, crop yield, combine nominal performance, working speed, header cutting width. The following is an example of the effective operation of a rotary combine harvester in comparison with a beater-drum one and its significant influence on the winter wheat grain quality of strong varieties. It has been proved that due to reducing the grain injury by the rotary threshing-separating unit, post-harvest ripening and cleaning on thrashing floor, it is possible to increase the grain quality indicators by one class.

1. Introduction

The problem of grain harvesting, as the most important agricultural product, remains acute and not fully resolved. The technical-economical indexes of domestic harvesting technologies are inferior to foreign ones in terms of energy intensity, labor costs, losses, etc. The national agriculture of Russia at the present stage of functioning, as noted in many domestic publications [1], cannot be competitive in the food market due to the use of agricultural technologies with low output parameters mainly, extensive in the investment and return of knowledge, capital and material resources. Only agro-technologies and machines of innovative type with a high level of knowledge and material and technical resources will help change the negative situation for the better.

The widely used technology of harvesting grain crops is labor-intensive, energy-intensive [2], allows large crop losses [3] and high costs [4]. In addition, modern grain combine harvesters (GCH) with threshing mechanism of a beater type, have increased grain crushing, reducing its quality [3]. It is
required to modernize the design of threshing devices and to optimize the parameters and operating modes of the machines [5]. Due to the low grain quality for various reasons, it is in a little demand abroad [6]. In increasing labor productivity, reducing costs, new technologies and a system of machines play a significant role [7, 8].

The structure and composition of the combine fleet in Russia has already exhausted its capabilities. Requirements for the combine design knowledge intensity should consider not only its reliability, productivity, operation quality, etc., but also a sharp decrease in costs due to the combination of operations.

Considering the above, the purpose of the article is to substantiate a new direction for increasing the productivity of combine harvesters and grain quality.

2. Materials and methods
Preparing the article, the results of production tests of modern combine harvesters [9] in agricultural enterprises of the Krasnodar Krai have been used, as well as the results of our own research [5, 7]. In analyzing test results of modern GCH, we have formed a system of estimated indicators (engine power, specific productivity, fuel consumption, grain loss), on the basis of which we have developed directions for increasing the combine productivity and the grain harvesting quality. By the grain harvesting quality, we mean not only direct and indirect losses, but also the protein and gluten content in the grain of a strong winter wheat.

3. Results and discussions
New directions for improving the GCH productivity and functional efficiency have been formed in Figure 1.

![Figure 1](image)

**Figure 1.** New directions for GCH performance increase.

In the three blocks of directions for increasing the combine harvester performance and quality (Fig. 1), the easiest for practical implementation is the second one – the GCH maximum performance usage. And exactly the analysis of the test results of modern combine harvesters in the Krasnodar Krai [9] showed that their technical capabilities are far from being used. The formula in this block interconnects the harvester performance $W$, its operating width $B_o$, the grain yield $U$ and the speed $V_o$. Unfortunately, underutilization of the working speed with an appropriate header width and yield, which leads to a decrease in the harvester performance $W$, and therefore to a decrease in efficiency, takes place. Scientific research has already been carried out on all types of these operations. An all-wheel-drive GCH, trailed or mounted on a device such as “Palesse” (Belarus) [10], can be used as an energy device.

The multifunctional harvester with the “Penha” pull-type GCH (Brazil) is of interest (Fig. 2).
The feature of the design and technological scheme of a pull-type Brazilian harvester is the design simplicity. Just past the header the rotary thresher is located, which has many advantages over beater-type threshers, and the main one is low grain damage, which determines its quality. Considering the need for a comprehensive harvesting process, it is easier to connect to a pull-type harvester, than to a self-propelled one to connect any pull-type implement for tillage, sowing catch crops, and pressing straw. For any traction resistance of a complex unit, it is easy to select a tractor in terms of tractive power, which is not easy to solve for a self-propelled harvester. At present, the level of automation of harvesting units and remote control over their operation no longer cause difficulties, using an on-board computer on the traction power unit and the necessary equipment on pull-type machines as part of the unit. The proposed unit in Figure 2 will provide indisputable efficiency, freeing up one tractor to aggregate the baler and the operator, which requires a lot of resources. In addition, by harvesting grain and immediately harvesting straw into bales, the unit increases labor productivity, saves costs and shortens the harvest period, the delay in which reduces the yield and increases its losses.

![Figure 2](image)

Figure 2. Trailing harvesting unit: 1 – header, 2 – rotor, 3 – transporter, 4 – hopper, 5 – frame, 6 – bar, 7 – Hooke joint, 8 – motion rod, 10 – straw, 11 – heap

There are known MFU, that have already been tested in harvesting with stubble plowing, harvesting with straw pressing, etc. [11].

![Figure 3](image)

Figure 3. Method of harvesting grain crops by stripping with simultaneous tillage.

In the second block for increasing the combine efficiency (Fig. 1), it is necessary to automatically link the combine parameters with the nominal performance: strict observance of the combine operating width $B_0$ (m), the grain yield (t/ha) and the combine harvester speed $V_c$ (km/h); the combine nominal performance $W$ (t/h) in each field should be automatically determined.

In the third block, it is necessary to carry out optimization calculations of the functioning of the harvesting-transport unit (HTU) for a specific grain yield, field size, distances to thrashing floor, combine and vehicle performances. Joint coordination of the HTU work on a computer, made it
possible to minimize the downtime of each unit. The optimization criterion is the combine holding time for its servicing by vehicle. In our calculations, it can be increased to 1.6 sec.

Improving the harvesting unit quality includes reducing direct (behind the combine) and indirect (from injury to grain) losses.

In the direction of increasing the combine productivity and the harvesting quality, high efficiency is provided by the technology of harvesting grain crops by stripping. This technology increases the harvester performance by 1.4 ... 1.5 times, saves resources, but, unfortunately, neither in our country, nor abroad, the multiple cleaning of harvesters is not suitable for an unwinnowed heap after stripping. It turns out that the stripper header is very effective, but modernized cleaning is needed for the physical and mechanical properties of the stripped heap in order to exclude grain high injury, which occurs in joint action of the stripping header and the series-produced threshing-separating device. Additional passage of the stripped heap through a series-produced threshing machine is fraught with increased crushing, grain micro-damage, which reduces its sowing and commercial properties. Our research has already outlined proposals for improving the threshing and separating unit, which will ensure an increase in the grain quality after stripping and reduce its losses. This will be a significant achievement in improving grain harvesting efficiency.

Many studies of grain harvesting technology with rotary combines and conventional threshing machines with a standard scheme have proven to reduce grain crushing up to ten times. And one more valuable conclusion has been made by us on the analysis of the wheat grain quality after these combines: due to the rotary thresher, it is possible to raise the grain quality by one class after its ripening on the thrashing floor and additional sorting. In our experiments, a strong wheat variety, when harvesting with a rotary harvester, in terms of gluten and protein content belonged to the 3rd class. After a month of refinement on thrashing floor and secondary cleaning, the quality analysis showed the level of grain of the second class, which could not be achieved in analyzing grain, harvested by conventional combines with standard threshers. During the secondary cleaning of wheat grain after ripening, it is necessary to pay attention to the selection of sieves, where the latter should be with long holes.

4. Conclusion
New directions of increasing the combine harvester performance and the quality of their work have been developed. Attention is drawn to the completion of harvesting units of three types: on the basis of all-wheel-drive, trailed and mounted harvesters, combining in one pass across the field harvesting grain and performing one of the accompanying operation – the stubble cultivation, pressing straw, sowing catch crops. A more compact unit is obtained on the basis of pull-type combines of the “Penha” type (Brazil) and a stripping adapter, according to our RU patent № 2357400.

The best harvesting quality is ensured by rotary harvesters, compared to the beater-type ones. They reduce grain crushing to ten times, micro-damage to several times and increase seed germination. Due to the reduction of grain injury of winter wheat of a strong variety, it was possible to raise the grain quality by one class after refinement on the thrashing floor.

To improve the grain quality of strong wheat varieties by one class in terms of protein and raw gluten content, they must be harvested only with rotary harvesters (preferably with TORUM-740 (750), and after ripening on thrashing floor, the secondary cleaning with sieves is to be carried out, where the last of them should be with oblong holes.

References
[1] Gritsyk V Yu, Bokov V E, Shirokikh A P et al 1994 Concept for the development of mechanization of grain harvesting for the period up to 2005 (Moscow)
[2] Resource saving in the technical operation of agricultural machinery 2002 Part I, II p 3
[3] Blednykh V V, Koslov N I, Rogoza V E, Uraikin V M 1998 Modern grain harvesters: state, trends and development concept (Chelyabinsk: ChGAU)
[4] Trubilin A I, Gayduk V I, Belkina E N, Kalitko S A and A E Gorokhova 2017 Infrastructure of
the regional agrifood market: Peculiarities of functioning and methods of improvement

Espacios 38 (33) 41

[5] Maslov G G, Trubilin E I, Truflyak E V 2016 Parameters Optimization for Multifunctional Aggregates in Plant Growing Mechanization Res. J. Pharm., Biol. Chem. Sci. 7 (3) 1919-1926

[6] Goltyapin V Ya 1998 Foreign harvesters: productivity, quality of work, fuel consumption Tractors and agricultural machines 8

[7] Maslov G G, Trubilin E I 2014 Rational process machines system for producing sunflower seeds and its efficiency World Applied Sciences Journal 29 (12) 1615-1620

[8] Maslov G G et al 2021 IOP Conf. Ser.: Earth Environ. Sci. 624 012107

[9] Scientific and practical recommendations for the selection of the most competitive harvesters for agricultural producers in the Kuban area Scientific Institution “Rosinformagrotech” (KubNIITiM)

[10] Maslov G G et al 2018 Rational System of Multifunctional Aggregates for Mechanization of Plant Growing Research Journal of pharmaceutical biological and chemical sciences 9(5) 1177-1185

[11] Khomenko A I, Cherepanov V G, Kofeynikova E V, Eremin N V et al 2009 Combined unit for harvesting and tillage RU patent № 2357400