Design of a threshing apparatus of the combine harvester of a new generation

G Kuzin¹, M Egorov¹,², N Mamchits¹, R Egorova¹, V Ishchenkova¹, A Atrokhov¹, and N Ugrekhelidze¹

¹Don State Technical University, Gagarin sq., 1, Rostov on Don, 344003, Russia

E-mail: ²aquavdonsk@mail.ru

Abstract. A patented, field-proven threshing and separating device for a combine harvester, created taking into account the elasticity and discreteness of the steams, fractionation and transparency of the layer in the threshing space, is proposed.

1. Introduction
The working bodies of threshing machines of combine harvesters are a threshing machine, a grain cleaning machine, a straw cutter and a threshing device.

Threshing device - a more General name for the threshing machine, which is the defining working body of a complex machine - a combine harvester. The main purpose of the threshing machine is to disrupt the connections of grains with the flower and scales of the ear or panicles. Most threshing machines are characterized by a concomitant operation - the separation of free grains from the rest (non-grain) part of the plant mass. This operation is called separation. Therefore, the purpose of the threshing machine is to break the connections of grains - threshing and their separation. In the case when the separation process is intensified in the threshing machine due to additional technical means, such devices are considered to be threshing-separating devices (TSD).

Threshing machines and TSD are considered the main working bodies of the combine harvester, which determine the performance of its operation as a whole. If the threshing mass does not undergo serious changes before these working bodies and is only moved by the transporting working bodies of the combine, then in the process of its interaction with these devices and devices, qualitative changes in the mass occur and it is divided into two streams processed in parallel in the thresher. In addition, they are the main consumers of energy consumed by the combine thresher.

The threshing machine is designed for separating the grain from the spikelets, directing the threshed heap to the grain cleaning and moving the coarse heap to the bump beater and then to the straw manger or other separating surfaces.

Violation of the connection of grains with the elements of the ear (threshing) in existing threshing devices occurs due to the blows of the whips on the stems, including the ears, as a result of which they are involved in the threshing gap between the rapidly moving whips and the fixed cross bars of the drumsticks. The impact of whips on the stems is the first phase of threshing, in which up to 70...80% of the grain can be ground. The stems inside the threshing gap are subjected to strong compression, which causes the layer of stems to move with a whip due to the friction forces between them.
Moreover, the upper layer of stems moves faster than the lower one, held by the sub-drum bars. The whips of the drum, overtaking the stems, strike them continuously, causing threshing of grain.

Blows of whips and their sliding on stalks, sliding of stalks one relative to another and on a ribbed surface of a podbarabanja leads to vymolachivaniye of grains from ears that is accompanied by crushing and break of stalks. This is the second phase of threshing. During the interaction of the drum’s whips with the stems, the latter are exposed to various forces that cause them to deform. These include the forces of impact, grinding, compression, vibration, and centrifugation.

By design, the threshing apparatus is divided into modules, pin and combined. Modules come in single - and double-drum and pin - single-drum. In combined threshing machines, the first drum is pinned, and the second is double. Pin threshing machines threshing is carried out more rapidly than with stably. They are much more intensive to interrupt the straw, crush it. They are installed on rice harvesters and sometimes used for harvesting bread with high humidity.

One of the criteria for selecting agricultural machinery for harvesting is the design of the threshing system. As standard, combine harvesters are equipped with a rotary or drum-key type threshing and separating device (TSD). Hybrid devices combine both types of mechanisms. Machines with a drum MCU are more often used for harvesting grain crops in low-yielding fields. Machinery where a rotary threshing machine is installed is often used for corn.

In practice, the choice of LSG is not limited to the type of culture.

In the drum structure of the TSD, grain is threshed by two mechanisms. This is directly the drum and drumming. The design of the first mechanism determines the type of threshing machine:

- mobile;
- pin.

Simplified configuration of the drum is represented by a set of disks equipped with special straps – podreczniki. They are located parallel to the axis of the entire mechanism.

![Figure 1. Billable drum.](image)

The design is highlighted by the fact that podreczniki attached corrugated pests. Devices are installed alternately, alternating in the direction of the ruffles: to the right, to the left. This ensures an even distribution of the bread mass.

The drumming mechanism has a lattice configuration, which allows the ground grain to Wake up (up to 80%). The angle of coverage between it and the drum usually varies in the range of 125 – 146°. A higher value of this parameter increases the productivity of grain mass milling.
Both threshing mechanisms: the drum and the sub-drum are equipped with pins made in the form of a wedge. A fixed grid is installed between their rows, allowing parts of the threshed product to wake up further. This design is advantageous when working with wet grain mass. The relative disadvantage of the pin device is a strong crushing of straw.

Rotary threshing machine.

The main focus of the design is the elimination of impact when threshing grain. The axial-rotary mechanism takes the bread mass and moves it in a spiral. Threshing takes place by means of friction. This significantly reduces the percentage of broken grain, but negatively affects the straw. It simply wears away. Result: the axial-rotary device reduces the percentage of broken product below 1%. This value is maintained even when productivity increases:

- increasing the speed of the rotor;
- reducing the threshing gap.

A number of leading manufacturers of grain harvesting equipment use two rotors in the MSU. A striking example is the New Holland combines. In contrast, the Case and John Deere machines are equipped with a single rotor.

The most versatile type of culture is the design with a mobile threshing machine. By properly configuring the functional units of modern imported equipment, it is possible to reduce the level of grain loss. The value from 11% is approaching the values of rotary combines.
For fields with high yields and for corn harvesting, it is more profitable to use an axial-rotary scheme. However, you will need a special corn header, configured for wider aisles of this crop.

Recently, there was a discussion in scientific circles about the future of our combine harvester. The resulting debate touched on many issues of grain harvesting and, above all, the prospects for R&d in the field of combine engineering [1-5]. It is known that each stage of development of society is accompanied by an increase in the area of harvested crops, an increase in their productivity, and a diversification of harvesting conditions. In this regard, it can be argued that harvesting on time and without loss is a permanent social order. First of all, it determines the need for technical progress in the field of combine engineering. The most widely used combine of the classic single-drum design. Its main unit is a threshing and separating device (TSD), which generates straw and cleaning. Together they represent the threshing machine [6-9]. Classic TSD includes a beater drum and rod plank concave. In this case, it is assumed that the drum is the leading working organ with the whip in the main role. Satisfaction of the social order is usually associated with the growth of the combine fleet, an increase in the size of working bodies, improvement of cleaning conditions, and intensification of technological processes. The optimal number of machines and their dimensions are relatively easy to set within existing capabilities. Improving cleaning conditions requires a lot of time. Increasing the efficiency of technological processes is achieved as a result of long-term experimental and theoretical research.

2. Materials and methods
The size of the machines is primarily limited to the size of the TSD. They have now reached limits roughly equivalent to a feed of 8-10 kg/s. Further growth in accordance with the requirements of the society (social order) based on extensive development is impossible for a number of reasons, including transport restrictions. There is a "dimensional dead end". It is logical to connect its overcoming with the possibilities of the theory. The effectiveness of the theoretical analysis depends primarily on taking into account the properties of the processed material. The threshable material is a multicomponent environment with variable properties, subject to various influences, and it is impossible to calculate the behavior of many of its components today. A large number of scientific papers are devoted to threshing. There are so many of them that it is very difficult to present a generalized picture of threshing. And first of all, to form an idea of the structure and movement of the working environment. Due to the extreme complexity and insufficient knowledge of the threshing process, a number of assumptions have been made, the most important of which is the assumption of thick-layer movement of the bread mass in the threshing space. The whole theory is based on this view with all the consequences. The set of all assumptions is such that the author of the article [1-5] concluded that the existing system of equations describing the processes of threshing and separation in the threshing space is of low significance. According to the author, the recommended system of equations "...does not reflect the real process of threshing and separation in the MSU» and «is so idealized that it does not represent any practical value... It allows you to set only the under – threshing and the amount of free grain at the output of the deck and only from one parameter-the length of the sub-drum [10-13]. Does not take into account the characteristics of the grain mass (solumitel, humidity and contamination, supply), and the design of the deck (number and step bars, their diameter, spacing and location of the installation the longitudinal bars in the deck, the entry angle, the radius of curvature, etc.). Not consider
Figure 4. Scheme of the threshing and separating device (in relation to the patent).

design of threshing drum (drum diameter and its frame, type the last form podvijnikov, the number and type of pests, etc.) and blog, as well as parameters of technological regulation of the threshing drum (gaps at the input and output kinematic mode) [14-16]. The science of grain combines was limited to the exponent. The key to success here may be to get rid of the accepted rough assumptions. Turning to science, you can not only theoretically evaluate what has been achieved in practice, but also take advantage of other opportunities that give it. First of all, the possibility of using the fundamental principle of improvement, based on taking into account new or known (but not taken into account) properties of the working environment. Another principle is based on the analysis of a large set of known statistical data, on the basis of which a new pattern can be established. In this regard, it can be argued that the use of these principles will change the design of the main working bodies of the TSD, making them more effective. Accounting for elastic and discrete stems, portionate coming to the threshing bread mass and factionalism of its members into the threshing space, a transparent layer, and analysis of the array of values of the diameters of the threshing drums helped to create TSD (see figure), which received a patent. Individual components and the TSD as a whole have been tested for operability and effectiveness during many years of laboratory tests and in economic conditions.

3. Results

The combine harvester with the threshing and separating device developed in DSTU, created in ООО «Agrotrade», tested in economic conditions with the assistance of ООО «Bison», showed results that, when eliminating the identified technical shortcomings, allow us to recommend it for wider testing in various regions of the country.

References

[1] Kuzin G, Barkov A, Prikolotin I, Antanosyan A 2018 ITNO-2018 (Rostov n/D: Don. gos. texn. un-t, Agrarny`j nauchny`j centr «Donskoj»)
[2] Akhalkatsi M, Otte A, Togonidze N, Bragvadze T, Mazanishvili L 2017 Annals of Agrarian Science 15 1 pp 11-16
[3] Khan A 2016 Annals of Agrarian Science 14 2 pp 25-34
[4] Guo C, Tang Y, Lu J, Zhu Y, Tian Y 2019 Agricultural and Forest Meteorology 272–273 pp 69-80
[5] Anderson W, Seager R, Baethgen W, Cane M 2018 Agricultural and Forest Meteorology The comparison of the reflectivity of millet and grain 25.32 21.05 25.4 22.36 28.14 27.6 33.3 26.31 24.5 24.52 27.83 27.1 0 10 20 30 40 50 The deflection angle of the strap, C Reflectivity, % Millet Average value (wheat, barley, oats) 262 pp 298-309
[6] Rosenzweig C, Jones J, Hatfield J, Ruane A, Winter J 2013 Agricultural and Forest Meteorology 170 pp 166-182
[7] Magney T, Eitel J, Huggins D, Vierling L 2016 Agricultural and Forest Meteorology 217 pp 46-60
[8] Chenu K, Roy Porter J, Martre P, Basso B, Asseng S 2017 Trends in Plant Science 22 pp 472-490
[9] Ewel J, Schreeg L, Sinclair T 2019 Trends in Plant Science 24 2 pp 121-129
[10] Abinasa M, Ayana A, Bultosa G 2011 Afr. J. Agric. Res. 6 17 3972e3979
[11] Maqbool R, Sajjad M, Khaliq I, Reham A, Khan A, Khan S 2010 Am-Euras. J. Agric. Environ. Sci. 8 2 pp 216-224
[12] Raghawanshi R 2012 Opportunities and challenges to sustainable agriculture in India NEBIO 3 2 78-86
[13] Akhalkatsi M 2015 Genetic Diversity and Erosion in Plants (Switzerland: Springer International Publishing,) pp 159-187 ISBN 978-3-319-25637-5
[14] Akhalkatsi M, Ekhvaia J, Asanidze Z 2012 Perspectives on Nature Conservation patterns Pressures and Prospects in Tech. Rijeka pp 51-92 http://dx.doi.org/10.5772/30286
[15] Girgvliani T 2010 The History of Aboriginal Forms of Wheat Varieties of the Upper Svaneti (Tbilisi: Artanuji)
[16] Patent for invention no. 2637129/ Threshing device/ Kuzin G. A./Application №2015136934