Ways to reduce injury to seeds by the harvester's final threshing device

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Abstract. The article deals with the problem of grain injury by the transporting bodies and the harvester's final threshing device. The assessment of the most characteristic operations causing micro- and macro trauma of grain is given. The most rational design parameters of machines and modes of their operation, which guarantee minimal injury to seeds, have been identified. Possible ways to reduce injury by reducing intense impacts, increasing the length of the separating surfaces for cleaning a combine harvester, and reducing the output of grain into the auger are identified.

1. Introduction

Stable growth of grain production is the most important task of the agro-industrial complex of the Russian Federation. Food security of the state is characterized by the gross harvest of all cultivated crops necessary to provide the population with food, livestock with a fodder base, as well as the creation of the necessary seed stock.

In the 21st century, grain harvesters remain the main means of harvesting cereals, legumes, cereals and other crops. A comprehensive analysis of the designs of grain harvesters of domestic and foreign production shows that the main directions of design and technological developments are those that have an impact on reducing the level of injury to seeds and commercial grain. To increase the throughput on modern combine harvesters, not only the drum diameter has been increased from 432 to 800 mm, but also the rotor length from 2612 to 3560 mm. At the same time, the cleaning area was increased from 3.55 to 6.5 m². The increased hopper volume helps to reduce downtime when unloading grain into vehicles and increases the productivity of the combine harvester.

The level of injury to grain during harvesting depends on the design and technological parameters of the working bodies and their elements. Along with the main working body of the ISU - the drum, the final threshing device has an important influence on the threshing process, in our opinion. In modern grain harvesters, it is not excluded that loosely milled grain can be removed into the chamber of the ear auger and fed for processing into an autonomous or other device.

Special attention is paid to the issues of improving the technology of finalizing the heap of the harvested crop, both in our country and abroad. In the designs of grain harvesters, many different schemes for finalizing the heap of ears have been proposed, which, in our opinion, can be combined into the following groups:

- Scheme of threshing and separation of the ear heap with the main threshing and separating device;
• Working bodies and devices allowing to implement a combined method of finalizing a heap of ears;
• A scheme of threshing a heap of ears with a final threshing device with the supply of threshing products for cleaning or straw walkers or simultaneously for cleaning and straw walkers;
• Device for finalizing a heap of ears with a final threshing apparatus in a single stream;
• Autonomous after-threshing devices with a heap feed for cleaning.

Studies [1-9] have established that one of the main disadvantages of modern domestic and foreign combines, which has a significant impact on the level of injury to seed, is the presence of a circulating load in their technological schemes (output of a heap into the chamber of the spike auger and feeding it for revision).

2. Materials and methods
The process of circulation of the heap in the thresher of a combine harvester can be estimated by the expression [1; 5]:

$$g_c = a^{n_c}$$  
(1)

Where \(a\) is the amount of grain supplied for cleaning, kg; \(n_c\) – sequence number of the cycle; \(b\) – coefficient determined by the physical and mechanical properties of the culture.

The circulating load depends on the total mass of the grain heap supplied to the grain harvester for cleaning, the modes of cleaning and the system for processing the heap, as well as the physical and mechanical properties of the harvested crop, determined by the coefficient \(b\) and the sequence number of the cycle.

It is known [1; 4; 7; 9] that with correct adjustments of the MSU and cleaning the grain harvester, from 7 to 15% of the grain mass from the total feed to the thresher enters the chamber of the auger. When grain harvesters are operating on farms in fields with a slope steepness of more than 8o, more than 40% of freely milled grain is carried into the chamber of the ear auger. In this case, the content of free grain in the circulating heap reaches 50% and more. Along with the circulation of freely threshed grain, torn, not threshed ears also enter the chamber of the spike auger. It has been established [1; 4-5] that the amount of circulating grain in unmilled ears returning for cleaning can be determined by the expression:

$$X_c = \sum_{i=1}^{n} X_{i-1}(1-e^{a_2 L_2}) \cdot e^{-A_2 A_3}$$  
(2)

Where \(X_c\) – is the amount of circulating grain with an unmilled ear; \(X_{i-1}\) – the amount of unmilled grain supplied for cleaning after the previous processing cycle; \(a_2\) – coefficient of separation of non-threshed ears on the extension of the upper sieve; \(L_2\) – length of the separating surface of the extension; \(A_1, A_2\) – intensity factors for threshing ears by transporting bodies and a final threshing device.

Autonomous after-threshing devices are installed on most modern Russian-made combine harvesters and combines from neighboring countries. With this scheme, the heap of the threshed crop coming off the sieves of the cleaning of the combine enters the chamber of the ear auger, goes to the elevator and is fed for the final threshing to the autonomous final threshing device. The feed for final threshing leads to an increase in the degree of both macro- and micro-injury to the seeds, and its supply by the distribution auger for cleaning leads to a deterioration in the separating ability due to the additional load and an increase in grain losses behind the thresher of the combine.

In our opinion, the advantages of this scheme of the technological process for finalizing the heap of wheat include the following:

• The main threshing apparatus is not overloaded with a fine, milled heap;
The efficiency of separation of threshed grain through the concave is improved;
Increases the productivity of the combine harvester;
The level of injury to seeds is reduced;
Their sowing qualities are improved.

3. Results
In the laboratory conditions of the Department of Agricultural Machines, Tractors and Cars on a specially prepared installation [1; 8; 10-11], studies were carried out on various designs of pre-threshing devices:

- Factory version;
- With removed cast-iron hammers;
- With installed blade cage;
- With installed passive tray;
- With an installed dividing screen in front of the after-threshing device.

The operating mode and technological adjustments of the working bodies of the installation corresponded to the operating mode of the combine harvester. The composition of the components included in the original heap was selected in accordance with the average values based on the results of many years of research on the composition of the heap in the field.

The moisture content of winter wheat grain was 15.1% and chaff 8.2%. The composition of the initial heap is shown in table 1.

| Components        | Pure grain | 1   | 2   | 3   | 4   | 5   | 6   | 7   |
|-------------------|------------|-----|-----|-----|-----|-----|-----|-----|
|                   | Unmilled ears | 1.6 | 3.2 | 4.8 | 6.4 | 8.0 | 9.6 | 11.2|
| Polova            | 6.4        | 13.8| 19.2| 25.6| 32.0| 38.4| 44.8|

The most important indicators characterizing the energy efficiency of cleaning a combine harvester are:

- Coefficient of separation of non-threshed ears through the extension of the upper sieve;
- Loss of grain in unmilled ears;
- The content of grain in the heap of spike that got into the chamber of the spike auger;
- Loss of free grain;
- Indicators of intensity of threshing by transporting bodies and a final threshing device (coefficients $A_1$ and $A_2$).

The obtained experimental data are shown in table 2.

It can be seen from table 2 that with an increase in the cleaning load of a combine harvester from 1.0 to 7.0 kg / s, a decrease in the separation coefficient from 0.9 to 0.11 is observed. This is because an increase in the cleaning load leads to a significant deterioration in the separating ability of the upper cleaning sieve and its extension. The amount of grain in a heap of ears increases from 25.0 to 82.0%. It should be noted that this is mainly free grain, therefore, any mechanical effects of working organs and final threshing devices will lead to an increase in macro- and micro-injury to seeds. Loss of free grain with an increase in the cleaning load increases and when the heap feed is 7.0 kg / s, it is 2.53%.
Table 2. The main indicators of the cleaning and final threshing device.

| Indicators                                                   | 1   | 2   | 3   | 4   | 5   | 6   | 7   |
|--------------------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|
| Separation coefficient of unthreaded ears through the extension, $\alpha$ | 0.90| 0.82| 0.78| 0.64| 0.44| 0.22| 0.11|
| Free grain content in a heap of spike, percent               | 25  | 40  | 51  | 58  | 66  | 77  | 82  |
| Loss of free grain (due to waste), percent                  | 0.25| 0.28| 0.48| 0.89| 1.45| 1.62| 2.53|
| Loss of grain in unmilled ears, percent                      | 40  | 25  | 18  | 20  | 24  | 26  | 28  |
| Threshing intensity factor by transporting bodies, $A_1$     | 0.80| 0.75| 0.70| 0.60| 0.48| 0.34| 0.21|
| Threshing intensity factor with a final threshing device, $A_2$ | 4.4 | 4.1 | 3.8 | 3.5 | 3.1 | 2.8 | 2.6 |

With an increase in feed from 1.0 to 3.0 kg/s, the loss of grain in unmilled ears first decreases and then increases. An increase in the loss of unmilled grain over 3.0 kg/s is due to a deterioration in the separating ability of the upper cleaning sieve of the grain harvester and its extension. Unthreaded ears, descended from the upper sieve and its extension, which have fallen into the chamber of the return auger, are fed into an autonomous after-threshing device for repeated threshing, first with the auger and then with a scraper conveyor.

Partially they are threshed with a screw, conveyor scrapers and main working bodies. The completeness of their threshing depends on the physical and mechanical properties of the heap being processed, the design and operating parameters of the corresponding devices. The coefficients of the intensity of threshing unthrilled ears by the transporting working bodies and the final threshing device are qualitative indicators of their work.

Analysis of the experimental data (table 2) shows that with an increase in the supply of a heap for cleaning, the coefficients $A_1$ and $A_2$ decrease at the noted feeds from 0.50 to 0.21 and from 4.4 to 2.6. This pattern is explained by a decrease in the likelihood of contact of non-threshed ears with the surfaces of transporting bodies and working bodies of the final threshing systems.

4. Discussion
Injury of seed and marketable grain depends on the physical and mechanical properties of the harvested crop, structural and regime working organs, grain harvester [3; 6; 8; 10-11].

The results of laboratory studies on the effect of loading on performance indicators are presented in table 3.

From the data presented in table 3, it can be seen that with an increase in the cleaning load, grain crushing decreases in all variants of studies of pre-threshing devices. The decrease in grain damage is explained by the fact that with an increase in the load, the likelihood of collision of grain with the working surfaces of cleaning, transporting bodies of the ear auger and the scraper conveyor of the final threshing device decreases.

5. Conclusion
The greatest damage to the grain was noted in the factory version of the final threshing device 0.92% and 2.52% at the corresponding feed. A heap of spikes caught in its chamber is subjected to impacts and chafing in the gap between the working surface of the hammer and the deaf deck. In this case, the probability of grain collisions with the working surfaces of this device is higher in comparison with other versions of the studied pre-threshing devices.

The smallest crushing of grain supplied for re-threshing is noted in the version of the final threshing device with a separating sieve installed in front of it and is 0.5% and 1.2%, increasing with decreasing feed. In this embodiment, the grain from the supplied heap to the final threshing device is
separated before it is fed into the device chamber and has a low probability of collisions with its working surfaces.

Table 3. Influence of cleaning loading on grain crushing by combine cleaning elements.

| Indicators                                           | Heap feed for cleaning, kg/s |
|------------------------------------------------------|------------------------------|
|                                                      | 1   | 2   | 3   | 4   | 5   | 6   | 7   |
| Grain crushing by cleaning, percent                  | 0.72 | 0.68 | 0.53 | 0.46 | 0.41 | 0.32 | 0.21 |
| Crushing of grain by cleaning and a final            | 1.20 | 0.98 | 0.92 | 0.74 | 0.68 | 0.61 | 0.50 |
| threshing device with a separating sieve, percent    | 1.36 | 1.28 | 1.22 | 0.91 | 0.82 | 0.74 | 0.71 |
| Crushing of grain by cleaning and final              | 1.58 | 1.46 | 1.28 | 0.98 | 0.89 | 0.79 | 0.76 |
| threshing device with the hammers removed, percent   | 1.98 | 1.66 | 1.48 | 1.12 | 0.98 | 0.88 | 0.81 |
| Crushing of grain by cleaning and final              | 2.52 | 2.21 | 1.82 | 1.74 | 1.61 | 1.12 | 0.92 |
| threshing device with a blade cage, percent          |     |     |     |     |     |     |     |

Summarizing the research results, it should be noted that one of the serious shortcomings of modern combine harvesters is the presence of a circulating load in their technological scheme.

With an increase in the cleaning load, the return of the spike heap for processing increases and the content of free grain in it at a feed of 7 kg/s reaches 82.0%.

It is possible to reduce the injury of grain by the transporting working bodies and the final threshing device by reducing intense impacts, increasing the length of the separating surfaces for cleaning the combine harvester, and reducing the output of grain into the spike auger.

The exclusion of the supply of free threshed grain for re-threshing reduces its crushing at the indicated feeds by 1.8 and 2.1 times.

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