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Concept Of Creating Energy-Resource-Saving Technologies For Harvesting Grain With Multifunctional Aggregates.

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ABSTRACT

The proposed concept of creating an energy-resource-saving technology for harvesting grain crops is aimed at increasing labor productivity, grain quality, integrated work and reducing the harmful effects of running systems on the soil. In four blocks of the conceptual scheme, the issues of energy and resource saving of the harvesting process, adaptation of machines, environmental safety and economic justification were considered. The optimum winter wheat harvesting time has been determined according to the developed economic-mathematical model with the objective function - minimum costs and losses. Depending on the cost of losses of grain harvest from the harvesting period, its biological losses and indirect losses associated with the traumatization of grain by the harvesting machinery working bodies are taken into account. New directions of modernization of harvesting technologies for grain crops are proposed, taking into account innovative technical solutions aimed at reducing crop losses, costs of all kinds, improving the quality of grain and the complexity of work. The significant effect of rotary harvesters on the improvement of grain quality in comparison with the billets has been proved.

Keywords: energy-resource-saving technology, grain harvesting, combine harvester, multifunctional aggregate, optimization, competitiveness.

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INTRODUCTION

Almost half of the cost of producing high-quality grain falls on harvesting. Unfortunately, the parameters of domestic grain harvesting technologies are inferior to foreign ones in terms of energy intensity, labor, money and other costs. In addition, the loss of grain to 10% of the crop [1], its injury to machines, the disruption of flow and rhythm, the complexity of harvesting and post-harvest operations, environmental requirements - require the transition to fundamentally new innovative design and technological solutions. Thus, a new methodology is required for an integrated, high-performance harvesting of grain crops, with simultaneous implementation of major post-harvest operations (stubble sowing, loosening of soil, harvesting of chaff and straw in the required volumes). All this is possible on the basis of a system of flexible energy-resource-saving multifunctional aggregates, which form the basis of the concept of creating such technologies [2].

The aim of the work is to increase labor productivity and reduce the costs of harvesting grain.

MATERIALS AND METHODS

The main research methods are the system approach, operation research, simulation and optimization of production processes, the theory of experiment planning, probability and mathematical statistics, MATLAB Simulink software, modern methods of economic and operational-technological evaluation of machine aggregates.

The method of analysis of technical and economic indicators of the operation of serial combine harvesters made it possible to establish that their further improvement has been practically exhausted [1-3]. Increasing the productivity of combines requires the increase of engine power, fuel consumption, mass, which already exceeds the permissible pressure on the soil, reducing its fertility [4]. Such a tendency to lag behind the increase in the productivity of the combine in t / h in comparison with the increase in the rated power of the engine in kW is characteristic of all self-propelled combines, both with classical and rotary threshing separating aggregates (TSA).

To optimize the harvesting time of winter wheat, an economic-mathematical model with a target function - minimum costs and losses (the cost of harvesting and harvesting losses due to deviation from the optimal harvesting time) has been developed.

$$C_{cl} = C_c + C_l \to \min, \quad (1)$$

where $C_{cl}, C_c, C_l -$ respectively, the amount of costs and losses, the amount of costs for harvesting grain and the amount of crop losses, thousand rubles.

In turn, the total cost of C_c for harvesting by a multifunctional harvesting unit after the transformation of the dependence looks like this:

$$C_c = \frac{F \cdot 1993,3 n_{agg}}{W_h}, \quad (2)$$

where n_{agg} – number of multifunctional aggregates (TSA) for harvesting area 1000 ha, pcs;
W_h - производительность TSA за 1 час основного времени, га/ч;
1993,3 - empirical coefficient;
F - harvested area, ha.

The amount of yield loss C_l, depending on the cleaning time n, will be determined by the following formula:

$$C_l = FzU\frac{(1{,}16n-4)+4{,}2}{100}, \qquad (3)$$

where z – purchasing price of wheat grain, rub / t;
U – grain yield, t / ha;
n – duration of harvest, days;
1,16; 4; 4,2 – empirical coefficients.

The novelty of the obtained dependence (3) consists in taking into account the cost of indirect crop losses from the crushing of grain by harvesting machines and from its microdamage. Expression in brackets [$\frac{(1{,}16n-4)+4{,}2}{100}$] takes into account the biological losses of the harvest after the full ripeness of the grain for each day of harvesting (n_i).

RESULTS AND DISCUSSION

The development of effective technology, including for harvesting grain crops, is based on the implementation of four blocks of the conceptual scheme for its creation (Fig. 1). One of the main blocks of the concept is resource-saving. A resource-saving strategy for the whole of agriculture is of vital importance as a basis for ensuring the competitiveness of the agrarian sector of the economy.

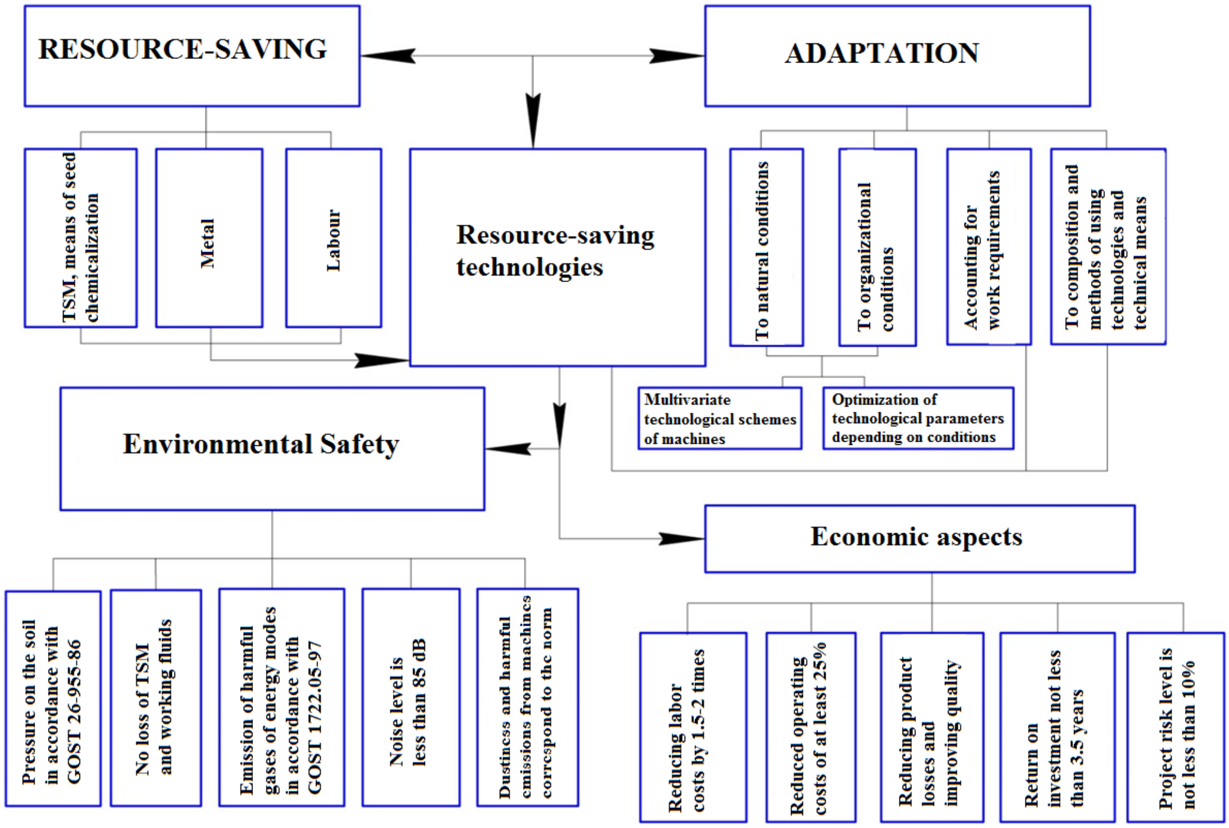

Figure 1: Blocks of the conceptual scheme for creating new technologies

According to the proposed scheme (Figure 1), resource saving in crop harvesting technology will be provided by saving fuel, metal, chemicals and manpower. Already now, some mass-produced cars efficiently save fuel by improving the fuel supply and spraying system, at the expense of the original operating elements, combining technological operations in one pass of the machine across the field, by optimizing technology options [5-7] and harvesting machine parameters [8].

The adaptation block of machines involved in technology takes into account the factors of natural and organizational conditions, the calculation of agricultural requirements, the composition and methods of using technological and technical means, taking into account the requirements for the work performed (direct and indirect crop losses, requirements for vehicles for harvesting, etc.). Subsystems for adaptation to natural and organizational conditions are used to optimize operational parameters depending on the operating conditions, taking into account the multivariate technological schemes of the machines.

The third block of the conceptual scheme for environmental safety of the technology being developed takes into account the pressure on the soil of the cars' running gear, the absence of losses of fuel and lubricants and working fluids, the emission of harmful gases by energy, noise level, dustiness and harmful emissions of machines at the operator's workplace. In addition, science has proven the harmful effects of compaction and spraying of soil by running systems of tractors and mobile machines. It is known that under the action of soil compaction its water-air and nutrient regimes of plant growth are violated, resistance to processing is increased by 1.3 ... 1.9 times. All this reduces the yield by 20 ... 40%. In the new developed technology of harvesting grain crops, harvesting machines and transport with a large mass, which compact the soil with running systems, can not be used. It is also necessary, by combining operations, to reduce the total number of passes of aggregates along the field, which is taken into account in our technology.

The fourth block of the scheme is devoted to the justification of the economic efficiency of the technology being developed. It should ensure a reduction in labor costs by at least 1.5 ... 2 times, operating costs - at least 25 percent, reducing grain losses and improving its quality. Return on investment should not be provided for more than 3 ... 3.5 years, and the project risk level should not exceed 10 percent. Thus, compliance with all four blocks of the conceptual scheme (Fig. 1) will create an effective machine technology.

Successful production of competitive agricultural products is largely determined by the modernization of harvesting technologies to reduce losses, improve quality and complexity of work. The saving of expenses for harvesting is determined mainly by the technique used for cleaning, which accounts for about half of all material and labor costs. The most important requirement for harvesting is to hold it in a tight schedule (4-5 days for wheat and 3 days for barley) and in conjunction with other related activities (closure of soil moisture, seeding of syderates and other intermediate crops, harvesting the non-grain part of the crop in necessary volumes, etc.). It is especially important to close the moisture for the future harvest. It is known that from every hectare of untreated arable land after stubble evaporates up to 100-150 tons of water, which reduces the future crop [4].

Unfortunately, such a complex and ambitious task has not yet been solved either in our country or abroad, and science is making only the first attempts to solve it. Multifunctional units (TSA) have been designed and tested that combine harvesting of grain and subsequent complex of works in one pass of the unit [2]. New designs of multi-purpose stubble cultivators are widely used, which, simultaneously with stubble cultivation, can introduce mineral fertilizers, level the soil and sow crop crops also in one pass through the field. When combining the work of such cultivators with a trailed combine harvester, the problem of complex harvesting is effectively solved. Undoubtedly, labor, energy, money resources will be reduced and, what is very important, the moisture is saved, the number of machine passes through the field is reduced, the soil structure and, hence, its fertility are preserved.

In the first block of resource-saving (Figure 1), the transportation of grain from harvesters, new ways of harvesting [1, 2, 3] and the optimization of the duration of harvesting operations are of great importance in the harvesting of grain crops [9]. On the transportation of grain from combines, only equipped storage devices - T-740 type reloaders are needed. It is impossible to compact the soil with heavy trucks, and even as part of road trains. This is soil reconsolidation and a decrease in the future harvest along the track of machines. We have established that, at distances of up to three kilometers, the overloaders themselves transport grain from harvesters to current, and over 3 km - they are transferred to heavy-duty vehicles such as Fliegl, waiting on the road, near the field. Labor intensity of grain transportation is reduced by 1.2 times, and fuel consumption is reduced by 1.6.

A new method of harvesting, for example, "neveika" with the division of an unbelievable heap in a hospital is still little used in practice, although its high efficiency in Canada has already been proven [10]. The method is based on the use of tractor grain combine harvesters MN130 and the original MH230 wax-cleaner with drive from a tractor or electric motor. The economic efficiency of the new harvesting method compared to self-propelled combine harvesters was $ 80 per hectare of harvesting area [10]. Impresses the high productivity of the MN130 harvesting unit with a 120 kW tractor. It is about 7 hectares for 1 hour of clean time, and the price of the trailed combine is several times lower than the self-propelled, in addition the maintenance and storage costs are reduced.

The use of flexible multifunctional aggregates (TSA) based on trailed combine harvesters working in the uninvited heap collection mode with its separation at the hospital, by combining the technological operations of harvesting grain with simultaneous execution of the main after-harvest works, solves the problem of their complex execution, flow and rhythm. The energy efficiency indicators of the proposed technology with the TSA underscore its significant advantage over the basic and high breakthrough effect (Table 1): the specific costs of aggregate energy and metal consumption are reduced by 1.7 ... 1.9 times, labor productivity is doubled.

As a result of our studies, the optimum duration of harvesting of winter wheat was established (Fig. 2). Each variety must be harvested within 4-5 calendar days, and only 5-6 varieties should be used in the agricultural enterprise. All this will help increase yield and save resources.

Table 1: Efficiency of wheat harvesting technology using TSA

Index	Technology options	
	basic	with TSA
Labor costs, person-h / ha	1,2	0,96
Operating costs, rub / ha	7702,6	6513,1
Metal consumption, kg / ha	49,8	41,9
Energy intensity, MJ / ha	602,5	702,7

In the new technology, efficiency is achieved for all indicators by means of TSA, combining harvesting of grain with straw pressing.

The optimization of cleaning n of the objective function (1) is obtained by its minimum value 5696 rubles / ha for the proposed cleaning unit m while pressing the straw, as well as components that function: cost value C_c = 2848 rubles / ha crop losses and cost

C_l = 2848 rub / ha. The minimum cost and loss function C_{cl} was obtained with the optimal work duration n = 4 calendar days, which is optimal.

In the creation of technical support for technology, one of the requirements for machines is the quality of the products obtained (block 4 of Figure 1). Especially it concerns the quality of wheat grain, which can be increased only due to the design of MSU harvesters. Our research shows that the use of rotary MSU for harvesting reduces the crushing of the grain 10 times compared to the bile, it reduces the microdamage by 6 ... 8%, and these factors influence the overall yield losses and the grain quality (Table 2).

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Table 2: Influence of the design of MSU harvesters when harvesting Olkhon wheat for grain grade

Fraction of grain	Indicators of grain quality								
	moisture content of grain,%	nature, g / dm³	total vitreousity,%	protein,%	Crude gluten				Class of grain
					%	Units IDK	Quality group	Characteristic	
Combine Tucano									
Before dividing into factions	10,10	824	69,7	14,24	23,21	52,3	I	хор.	3
3,0/20	10,10	840	74,2	15,62	25,84	54,8	I	хор.	3
2,5/20	10,15	832	70,1	14,38	23,80	52,6	I	хор.	3
2,2/20	9,91	785	67,5	13,42	19,48	53,9	I	хор.	4
1,7/20	9,66	736	58,5	10,42	16,04	38,9	II	удовл., крепкая	5
HCP_{05}	0,04	6	1,3	0,83	1,40	-	-	-	-
Combine Torum									
Before dividing into factions	10,49	824	81,9	17,81	26,63	58,90	I	хор.	3
3,0/20	10,34	845	85,2	19,68	31,12	65,00	I	хор.	2
2,5/20	10,63	828	82,4	17,86	26,40	59,80	I	хор.	3
2,2/20	9,99	782	77,2	14,85	21,56	44,80	I	хор.	4
1,7/20	9,76	731	67,4	14,39	20,20	43,09	I	хор.	4
HCP_{05}	0,12	7,2	2,7	0,56	0,84	-	-	-	-

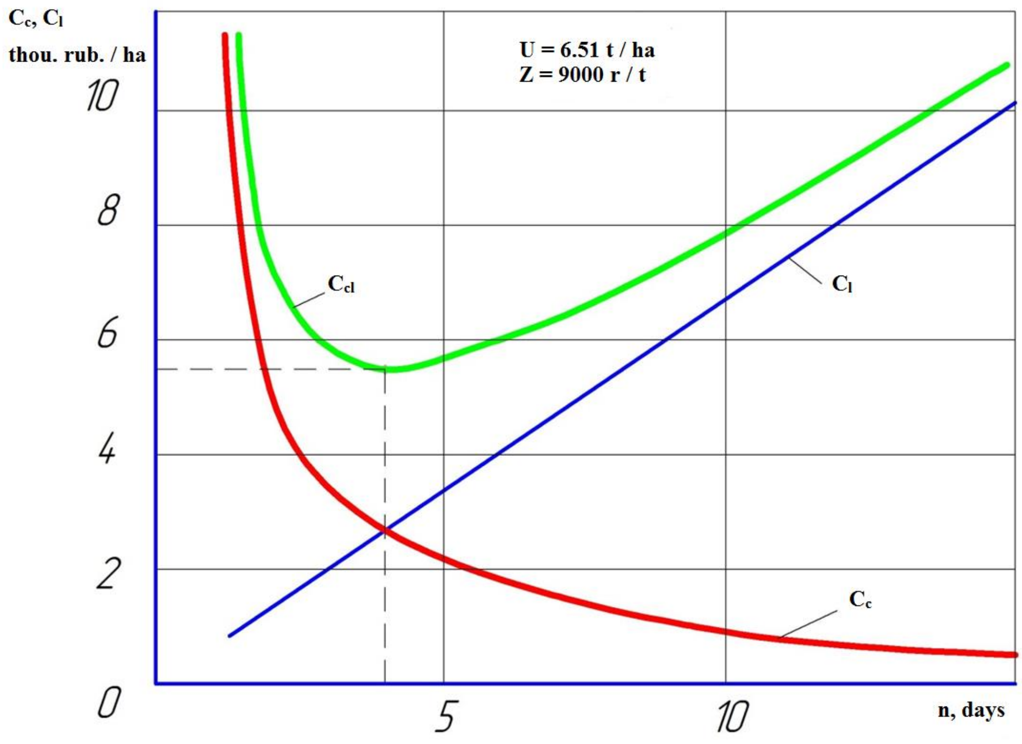

Figure 2: Dependence on the costs of harvesting grain and crop losses from the harvesting time

As the data in Table 2 show, the difference in the content of raw gluten and protein in Olkhon grains harvested by combines with MSU is significant both in grain in general and in sorting on sieves and in grain fractions. This difference between Tucano and Torum combines is due to the influence of grain microcracks during harvesting. The indices of grain nature, total vitreousness, quantity and quality of raw gluten allowed to determine the class of Olkhon wheat, as a whole as a result of harvesting by different harvesters, and by grain fractions (Table 2).

Thus, the proposed concept of creating energy-resource-saving technologies makes it easier to make a decision when developing it.

CONCLUSION

In the proposed concept for the creation of energy-resource-saving technologies for harvesting grain crops, four blocks are envisaged: energy saving, adaptation of machines to harvesting conditions, environmental protection and economic justification. In the first block, the main attention is paid to the replacement of heavy, expensive self-propelled combines with multifunctional flexible harvesting units combining grain harvesting operations with simultaneous performance of the main harvesting complex works (soil loosening, intermediate sowing or forage crops, straw pressing in the planned volumes). Multifunctional aggregates are completed on the basis of trailed non-motorized, self-propelled four-wheel-drive or hinged harvesters for mobile energy equipment. Experimental studies confirmed the significant advantage of multifunctional harvesting units using the example of the all-wheel drive combine TORUM-740 of the Rostselmash plant (Russia) with a set of aggregated machines and a hinged КЗР-10 for the MES-280 energy facility (Belarus). The most preferred method for harvesting grain cereal multifunctional aggregates is the "neveika" with separation of the heap at the hospital by MH230 aspiration-screen separators (Canada). With the use of the cost and loss function, the optimal harvesting time for cereal grains is justified - 4 ... 5 calendar days for one variety with different maturation periods. According to the recommendations of breeders in each agricultural enterprise, it is necessary to cultivate 5 ... 6 varieties of wheat, including strong, high-yielding, early, medium, etc. All this will effectively affect the yields, the quality of grain, and also on energy and resource saving.

Grain harvested by rotary MSU, after harvest ripening and sorting, can be raised to one step of a higher class, which is impossible with the use of the local government LSU.

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