On the development trends of the machine-tractor park of the agro-industrial complex of Russia

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Abstract. Currently, agricultural machinery is characterized by low technical level and high wear. The tractor fleet is basically based on outdated machines that do not meet modern requirements for the consumption of operating (fuel and oil) and construction materials, reliability, environmental impact (water and air basins, soil, the content of harmful impurities in exhaust gases), working conditions and level of automation and other indicators. The wide use of combined harvesters shows significant shortcomings typical of currently produced combine harvesters. Extremely high concentration of operations in one machine, typical of modern self-propelled combines, with high productivity, severe restrictions on harvesting, loss and damage to grain, with high requirements for durability and reliability leads to an increase in machine weight. As a result, there are problems to increase its cost, soil compaction during harvesting, reducing crop yields, and highly qualified personnel for operation, maintenance and repair. The article analyzes the trends of further development of agricultural machinery, based on the solutions proposed in the Russian-Belarusian patents, aimed at solving these problems.

1. Introduction
The current volume of tractor fleet in agriculture in Russia is about 1 million units of equipment. This indicator takes into account the machines operated by all types of agricultural producers: from large organizations to private lands [1].

Nowadays, agricultural machinery is characterized by low technical level and high wear. The tractor fleet is basically based on outdated models of machines that do not meet modern requirements for the consumption of operating (fuel and oil) and construction materials, reliability, environmental impact (water and air basins, soil, the content of harmful impurities in exhaust gases), working conditions and the level of automation and other indicators [1].

However, the steady development trend of the machine-tractor fleet of agro-industrial sector of Russia is the decrease in the flow of machinery: the replenishment of the machine-tractor fleet amounts to 4% per year, and the write-off is 8–11%. Over the past 10 years, the available fleet of agricultural equipment has decreased by 2.5 times for tractors, for grain and forage combined harvesters by 2.7 and 3.0 times respectively, and for equipment for livestock farming by 3-4 times [1].

2. Materials and methods
The wide use of combined harvesters shows significant shortcomings typical of currently produced combined harvesters. Extremely high concentration of operations in one machine, typical of modern self-propelled combines, with high productivity, severe restrictions on harvesting, loss and damage to
grain, with high requirements for durability and reliability leads to the increase in machine weight. This raises problems of high cost, soil compaction during harvesting, reducing crop yields, and highly qualified personnel for operation, maintenance and repair. Another problem of combined harvesting is the most crucial, coupled with the inevitable and very significant loss of time, the transfer organization of harvesting and transport operations, which leads to the decrease in the operational performance of harvesting complex [2].

The complete exhaustion of the capabilities of classical scheme of a combined harvester is evidenced by the S-shaped character of the development curves of combine parameters over time. It is given in the work of A.I. Rusanov and G.M. Zhuravleva [3]. It is enough to differentiate such an integral curve, and a sharp drop in the increase of parameters over time becomes apparent, indicating the exhaustion of the possibilities of the scheme of such a combined harvester.

The scientists from Don State University in their research work [4] evaluate the urgent innovations in harvesting equipment. The attacks on classical scheme of a combined harvester are being carried out for the last 200 years of the history of combine-building with varying degrees of success. In the last 40-50 years, in parallel with the concentration of production of combined harvesters, these attacks have become not only serious, but also largely successful. The undoubtedly successful attacks on classical scheme of a combined harvester include the creation and mastering of the production of tractor drawn combined harvester “Prostor” and mounted-trailed combined harvester PN-100 with rotary threshing and separating devices for “Polesye” electricity operating company (EOC) [5].

Quite successful attacks on classical technological harvesting schemes also include the Neveyka schemes developed in Zernograd under the guidance of E. I. Lipkovich, the academician of Russian Academy of Agricultural Sciences, the “industrial” harvesting method implemented in the village of Kanevvskaya, and the so-called “Kazakh” method of harvesting.

The sticking point for the wide introduction of the “Neveyka”, “Kanevsky” and “Kazakh” methods was the delivery “to facility” for cleaning (“Neveyka”) or threshing and cleaning (“Kanevskaya”) of grain-straw mass, the density of which for “Neveyka” did not exceed 200 kg / m³, and for “Kanevsky” method it did not exceed 50 - 70 kg / m³.

The Department of Agricultural Machines of the DSTU also developed a system of models for forecasting the development of mechanization tools, including scenario forecasts of technical demand, synthesis of circuit solutions and constructive implementations of these schemes based on fuzzy sets theory [6].

As a result of the forecasts made for the investigated development scenarios, a grain harvester mounted on power tool (tractor), a harvesting machine of which includes a reaping part, rotary threshing and separating device with a throughput of 4–5 kg/s, a vertical air separator and a conveyor belt will be in the greatest demand. Grain pile cleaned in the air canal accumulates in tractor tanker. The difference from the previously studied “Neveyka” scheme is that the transportation to the existing stationary grain cleaning units (typical or with partial modernization) occurs through a “blown” grain pile of (natural weight) 600-650 kg/m³.

According to the cited specialists, the grain harvesting unit should be a header mounted on a reaper, coaxially with an auger of which an axial rotary threshing and separating device is installed (attempts were made to combine the axial rotary threshing and separating device and a header in state special design bureau “Rostselmash” in 1952-1954, but were not completed due to technological problems of that level of production development). The run of threshing and separating device – grain, chaff, harvester, spikelets, with bulk density of 150-180 kg/m³, are fed into a vertical air separator. The descent of the threshing and separating device - a pile of straw - after crushing (or without crushing) spreads across the field. At a height of the air-separating channel of about 1.5 m, the density of the grain pile accumulated in the trailed tanker will be 600-650 kg/m³, which is already quite acceptable for transportation. According to our assessments, the power required for the drive of such a harvester will not exceed 40–45 kW [4].

In order to expand the possibilities of aggregation of harvesting machines, as a result of targeted search and system evaluation of options on simulation models of harvest-transport complexes at DSTU,
it was possible to synthesize schemes and design solutions of mechanization tools that provide the above-mentioned technological process, but consuming up to 28–30 kW for drives (corresponds to the capabilities of the drive from raw-crop tractor).

For these machines, the organization of unit interaction was found, providing the transition from “transfer” to a more capacious, “transshipment” technology of the organization of harvest-transport complex, excluding the waste of waiting time during the interaction of workers and transport links of a complex. In addition, the organization of technological process of this complex allows not wasting, but accumulating a valuable component of farm animals feed - the chaff (output fraction after the air-separator).

The possibility of introducing one more specialized unit into the complex will allow receiving granulated feed from accumulated chaff.

The harvesting and processing complex proposed for this technology should include three successively operating units: harvesting, cleaning and the unit for the production of granulated feed.

During the course of the research the authors of the works [4, 6] drew the following conclusions that

- The cost of harvesting unit with an air-steam channel will be 50% of the cost of a trailed or 30% of the cost of a self-propelled combined harvester,
- The cost of a set of harvesting and cleaning machines will be 40% less than that of a trailer, and 60% less than the cost of a self-propelled combined harvester of the same turnover.
- Effective demand for these machines, even with the current level of income in agriculture, can reach 30 thousand units per year, in addition to the existing sales of combined harvesters.

However, it is necessary to note that the wheeled agricultural tractor used as the energy base of the transport unit in its parameters also does not meet the requirements as a transport vehicle. A tractor is a traction machine, designed to work with high average tractive power and relatively low speeds. The main purpose of a tractor is to activate technological and transport-technological machines with passive and active working units.

Thus, the tractor means of the agro-industrial complex do not fully satisfy the contradictory requirements of agricultural production.

The above-mentioned problems occupy special place in the Basic Provisions of Forecast of scientific and technological development of agro-industrial complex of the Russian Federation for the period until 2030, approved at a joint meeting of the Presidium and the Collegium of the Scientific and Technical Council of the Ministry of Agriculture of Russia on March 30, 2016, and in the Basic Provisions of Forecast of scientific and technological development of agro-industrial complex of the Russian Federation for the period until 2030, approved at a meeting of the Government Commission on the issues of agro-industrial complex and sustainable development of rural areas on December 13, 2016.

Thus for agricultural sector, the universal power means are needed that are developed taking into account the peculiarities of exploitation under the conditions of agriculture.

3. Results and discussion

Nowadays, the following main trends in the development of tractor equipment are outlined:

- The increase in the power and capacity of vehicles;
- The expansion of working functions;
- The universalization of power base and tractor means;
- The use of modular type tractor tools with replaceable and transforming working equipment;
- The increase of supportive, profile and horizontal flow;
- The hydraulic processing of power drives and control drives;
- The automation of management and regulation on individual operations, etc.

Taking into account the above mentioned fact, there is the need to create agricultural production of a new generation of modular type tractor tools based on the extensive use of modern information
technologies for automation and robotization of technological processes, which, in our opinion, can serve as the basis for a new research direction.

The design idea of the creators of UES-2-250A (UES-2-280A) (“Polesye” 2U250A (2U280A)) universal power facilities is in this direction to some extent. This universal power means is intended for performance of various agricultural tasks which are carried out in the unit with semi-mounted, mounted, trailed machines and tools. The power unit is equipped with a mounted device for the aggregation with various machines and a controlled drive axle to provide all-terrain and tractive capability. Depending on the need to move forward or backward, the work position of an operator may be reversed.

According to the representations of creators the advantages are as follows:
1) The possibility of transferring 100% of engine power through power shafts is realized in a vehicle, which allows effectively aggregating with machines and combined harvesters with active working elements that consume a significant part of engine power.
2) The presence of front and rear power take-off shafts makes it possible to aggregate agricultural machinery on two sides of a power plant, using them in one complex, which reduces the number of runs across the field.
3) The use of powerful mounted devices made it possible to reduce the mass of mounted machines in comparison with similar trailed machines used in the unit with universal tractors.
4) The air intake of radiator is self-cleaning.
5) The hydraulic drive allows smooth adjusting the speed of movement, ensuring stable operation of mounted machines.
6) The reversible operating place provides the transition from a forward stroke to a reverse in less than 1 minute.
7) The high location of a cab provides the same good visibility of the working units as for self-propelled combines.
8) Universal power unit is used from May - June to October with mounted machines produced by “Gomselmash”, for grass mowing, crushed fodder harvesting, grain and corn harvesting, as well as sugar beet. This determines the high economic efficiency of machine complexes based on electrical resistivity compared with special self-propelled combined harvesters of a similar class.

In this regard, it is necessary to refer to the work [7], in which the characteristics of the indicated universal mobile power facilities are evaluated. In particular, it indicates that the use of universal mobile power tools for block-modular principle of aggregation with technological modules-adapters (harvesting and other purposes) due to their greater annual load will reduce the cost of mechanized work and production. In addition, it is noted that the wheels of universal power unit (“Polesye”) is equipped with front and rear mounted hydraulic systems used in the aggregation with blocks of harvesting module. The authors speak positively about the aggregation scheme - “... it is very effective, the serial production of KZR-10 grain-harvesting units was adjusted on its basis.” [7]. However, the disadvantages are also noted: the adopted scheme of connection with the wheels of reaping part and threshing device leads to the overload of carrying bridge, and the system for transporting material from threshing device to towed grain cleaner is not well formed, which degrades the quality of its work. The use of a single-axle wheels layout with small-diameter wheels reduces its carrying capacity. In addition, the authors note that the method of rolling the harvest modules through the example of “Claas” company on “Hukepak” G-85-BM wheels and on SS-75 wheels of Taganrog combined harvester plant is implemented using manual labor.

In the same research work, the stages of development of this direction are shown through the example of the “Karl Hürt” and “Claas” (Germany) enterprises as well as “Gomselmash” (Belarus) and Taganrog Combined Harvester Plant - (Soviet Union).

The next stage of development of harvesting units based on universal power means is presented by the solutions of the patents of “Claas” (Germany), SKNIIMESKH (Russia), and “Gomselmash” (Belarus) enterprises.
4. Conclusion
The general advantages of the proposed solutions are as follows: the use of wheels of the same diameter; the ability to install one of the blocks of the harvesting module on the frame of wheels.

The authors of the research work [7] point out the shortcomings of the solutions in the patents of “Claas” enterprise: the mounting of harvesting, threshing and transporting modules on the front mounted system of wheels, as well as the absence of its own loading mechanism on it.

They also believe that the advantages proposed in the Russian-Belarusian patent solutions are the availability of loading devices to replace harvesting modules, combined with a change in the location of control cabin, providing a direct-flow of processed material.

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