Agricultural tractors of the fifth generation

E.I. Lipkovich*, A.Y. Nesmiyanb, S.L. Nikitchenko, V.V. Shchirovd and Y.G. Kormilteve

a. Chief Researcher of the Scientific Department, Azov-Black Sea Engineering Institute of Don State Agricultural University, 347740, 21 Lenin Str., Zernograd, Russian Federation.
b. Department of Technology and Mechanization of Agriculture, Azov-Black Sea Engineering Institute of Don State Agricultural University, 347740, 21 Lenin Str., Zernograd, Russian Federation.
c. Department of Technical Service in Agro-Industrial Complex, Azov-Black Sea Engineering Institute of Don State Agricultural University, 347740, 21 Lenin Str., Zernograd, Russian Federation.
d. Chief engineer of the Engineering and Transfer Center, Azov-Black Sea Engineering Institute of Don State Agricultural University, 347740, 21 Lenin Str., Zernograd, Russian Federation.
e. LLC "Research and production inculcation firm "Tenzor-T", 347916, 11-49 Vishnevaya Str. Taganrog, Russian Federation.

Abstract. In article described problem of substantiation of mobile power units (MPU) – tractors for agriculture of the fifth generation. Purpose of the work is to analyze agricultural tractors of the fifth generation. Showed technogenic interaction of MPUs with production processes in agro-ecosystems of grain production in the zonal conditions of South-Russian arid agriculture. Proposals of new MPUs have been developed; the technological structures of machine aggregates based on the MPU of the fifth generation of classes 3, 5-6 and 8 that determined the technical schemes of the named MPU were determined. Analytical models for calculating the power characteristics of MPU of the named classes in deterministic and stochastic modes in relation to the most energy-intensive operations with definitions of the mathematical expectations of MTA’s power and performance. Analysed of the MTAs effectiveness based on new MPUs upon criterion of the time spent on cultivating crop rotations, for classes 2, 5-6 in wheeled and caterpillar performance, and applied to technological services type of MTS of the new generation. The comparison was carried out on the same sites with MTA using fourth-generation tractors. The time costs are reduced by 1.4 ... 1.5 times, and for MPU of class 8 – up to 2.3 times.

KEYWORDS Machine-tractor unit; Mobile energy facility; Structural and analytical model; Stochastic process; Crop rotation; Mathematical expectation.

1. Introduction

For more than a century the world’s agriculture has been using agricultural tractors, which have been transformed from a simple primitive machine with steel wheels equipped with metal grippers and small-sized, at a rate of 1.5 dozen hp., engine up to robotic technical means with excellent ergonomic conditions, space control of technological process, capacity of ICE by 20 ... 30 times higher than originally. This new modern machine allowed to raise labor productivity at least by 20 times.

But one property of a modern tractor, both wheeled and caterpillar, has remained unchanged. This property of aggregating agricultural machines with a tractor, which remained virtually unchanged: tractor became a "steel horse" according to the technological scheme, having one rear hook and a single rear hinged system. At the present time the tractor is equipped with a multi-section, rather long train of successively working tools requiring a wide turning strip on the field being processed; and, despite the highest level of automation, with the increase in the number of operations in a single machine and tractor unit, the MTA’s cumbersomeness consistently increases and, if anything, technological reliability (also consistently) decreases.

* Corresponding author. E-mail address 4ye@mail.ru (E.I. Lipkovich)
In addition, the increased mass of the tractor, primarily wheeled, sharply worsens the ecological working conditions due to an increase in the specific pressure on the soil with a deep force effect on the arable and subsoil layers; the actual pressing of the soil along the wheel tracks is carried out, and the relatively high slipping and grinding of soil aggregates worsens the structure of the arable layer and contributes to the occurrence of wind erosion [1, 12, 16].

There is a need to find ways to improve the technological capabilities of a modern tractor in order to increase the adequacy of mechanical and technological systems in the form of machine-tractor units (MTA) to production processes in agroecosystems.

The current problem of the development of mobile power engineering in the AIC is to find and justify the ways of the optimal technogenic interaction of agricultural tractors and the technological MTAs completed on their base, which reduce the negative impact of running systems on the arable layer of the soil, reduce the intensity of erosion processes, increase the reliability of multi-operation MTAs, synthesized (collected) on the coupling devices.

2. Materials and methods

The authors used different methods to achieve the set goal. The analysis of numerous studies in Russian and world agroengineering has shown that one of the rational ways to reduce the harmful man-caused impact on the productive layer of soil of mobile aggregates is the organization of soil cultivation and cultivation of field crops with a minimum number of drills along the processed field surface, while reducing the specific pressure from the impact of running systems. And if the problem of reducing pressure on the soil is, in general, understandable in its radical decision: it is a substitute of wheeled movers of mobile power units and technological self-propelled machines by caterpillar tracks for use in soil cultivation, sowing or harvesting, then the decision to reduce the number of MTA passes through the field is not plain to see. This decision has not yet been formed, if we bear in mind the almost complete use of the capabilities of a modern tractor, both in wheeled and caterpillar design, in this sense. We must immediately note that in this paper we are talking about heavy tractors of agricultural class 3 and above, which, basically, "make" the harvest of significant commodity producers. This applies to those mobile power units that are still operating today, representing the fourth generation of mobile power engineering and having the technical structure that developed at the dawn of their use (i.e., the unchanged technical structure, as noted above).

One more feature of the MTA composition should be noted, which are formed on the tractor on the rear trailing device or hinged system. It is clear that a set of trailer machines ensures the performance of a multi-process complex operation, i.e. such an operation, when the expected positions of which (transitions) can be fulfilled in a single agro-term – simultaneously, in fact [14]. Thus, multiprocessing aggregates arise, the application of which is precisely aimed at reducing the number of passes through the field, which is the essence of public soil-saving measures. But such an aggregate, as a rule, is rather complicated, poorly controlled, not flexible on the trajectory of motion when performing the technological process. The creation of multiprocessing tools and machines as, for example, world-known disk headers, and in Russia – multi-purpose tillers for preparing soil for sowing winter crops on non-steam predecessors, seems to be an improvement of the process [2]. However, combined guns and their aggregates especially are rather cumbersome and heavy, their negative property is the inclusion of several robot-like working elements in the unit, connected not so much by the sequence of operations as purely geometrically. All the structural, technological and organizational difficulties mentioned here have a common root cause: the imperfection of the engineering and technical structure of the fourth generation tractor (as well as the previous ones), which manifested itself gradually and consistently, reached its maximum at the present stage of the machine and technological support evolution.

In other words, in its development, the world’s tractor equipment has lagged behind
itself: from powerful fast-growing characteristics, from fast-growing mass, from the level of control systems, from the ergonomic level [3, 13], from the requirements of ecological balance of technogenic interaction with production agroecosystems; finally, from the level of machine technologies for the production of field crop production and the system for organizing field work development. As is often the case, a certain (probabilistic) tilt in the growth intensity and development of purely engineering and organizational-technological problems in mobile power engineering has occurred in developing technology [4].

Thus, the solution of the problem posed may lie in the ways of justifying and developing mobile energy resources of the fifth generation already – not tractors, but MPUs – machines of much greater capabilities than the traditional tractor, more sophisticated at the core components, but with mandatory consideration and preservation of all technological properties of tractors of the fourth generation. This, in turn, retains the fundamental property of modern tractors, which passes into the next generation: their separation according to the classes of thrust with the corresponding mass-energy characteristics [5, 6] and so that the new, fifth generation of MPU could confidently be aggregated with the same tools and machines with which the fourth generation tractors work and form various functional or multifunctional MTAs.

3. Results and discussion

Machine-tractor units, in which MPU of the fifth generation is the main link, are synthesized directly for field work in zonal rotations on a multifunctional, multiprocess basis, i.e. with the provision of production of several technological operations that have the same agro-term or can be technologically carried out in a single agro-term. This reduces the total number of operations, the number of passes of heavy equipment on the plow layer, and if we add a significant increase in the use of tracked propellers to this, which was originally laid in the creation of a system of tractors for agriculture, including in the US, the structure of MPU of the fifth generation is coming close to realizing the requirements of ecological balance of technogenic processes of agrocenosis production [7, 8, 16, 17].

Actually, agrocenoses, implemented by zonal crop rotations or operations of technological services in agricultural organizations, APCs, peasant farms, the most labor intensive and of large volumes, directly set the agrotechnological structure of MTA, the derivatives of which are MPU of different classes [6, 9, 15].

The structure of MPU of the fifth generation, in order to ensure a rational synthesis of technological MTAs in zonal rotations and service and technological works, should include the following features (at least four):

– the presence of two universal hinged systems, front and rear;
– the presence of two independent unified shafts of power take-off, front and rear, providing up to 80 ... 85% of the energy transfer of rotary motion to power-driven machines, mounted on the front or rear attachment system or traction device;
– stepless drive of the undercarriage, hydraulic or electric (in this paper we consider MPU of the fifth generation with a stepless hydrostatic drive, which has been sufficiently developed and successfully used for a long time in the world agricultural machinery);
– wheeled MPUs of classes 3, 5-6 must be equipped with an easy-shift caterpillar chassis; while MPUs in wheel designs weighing more than 11.000 kg, based on long-term and very numerous studies, as well as long-term observations should be disused from field work.

We have chosen platforms, so to speak, field works of new MPUs:
– South-Russian grain-fodder crop rotation in arid agriculture with the use of black steam in relation to the peasant farms, an eight-field, with an area of 960 ha (farmer rotation);
– a large crop rotation in the same grain-fodder area, nine-field with the use of black steam, with an area of 2.250 hectares for agricultural organizations (APC, CAE, etc.);
– a set of labor-intensive field works in the form of technological service for surface
tillage (400 ha), subsoiling and other heavy surface tillage operations (3,500 hectares), harvesting of cereals (1,200 ha) and maize for silage (800 ha).

Operations on these volumes of work set the technical structure of the MPU of the three classes we are developing: 3, 5-6 and 8 – the main machines that "make" the harvest [6].

So, in Figure 1, the general layout of MPU-3200 of class 3 with power of 184 kW in wheel (a) and caterpillar (b) variants with the use of a replaceable running gear is shown. Based on this, MPUs are equipped with MTA for processing the named farmer crop rotation, with the exception of the spiked cereals harvesting process, which is performed by a self-propelled combine harvester (of medium or even small class).

The second crop rotation is processed by a complex of machines based on the caterpillar MPU-5400 of class 5 with a power of 260 kW ... 280 kW (Figure 2); the latter provides the acquisition of all necessary MTA, including the process of harvesting spiked cereals by a trailed non-motorized combine (Figure 3).

Figure 4 shows the scheme of fodder-soil-cultivating MTA on the basis of caterpillar MPU-5400; at the same time, the MTA is equipped with a trailing implement AKM-4 (6) to prepare the soil for sowing winter crops on non-steam predecessors (multi-process MTA) – simultaneously with harvesting maize for silage.

Figure 5 shows the physical model of MPU-5400 (scale 1:12) with two mounted tillage tools: disk (on the front mounted system) and a deep scraper (on the rear).

Figures 1, 2, 3, 4, 5

Finally, MTAs, equipped with a caterpillar MPU-8470 of class 8 with power up to 380 kW (Figures 6, 7), are used in service technological operations. At the same time, MPU of class 8 performs all harvesting operations, including harvesting of spiked cereal crops using a trailed, non-motor high-performance combine harvester (Figure 8).

Figures 6, 7, 8

Synthesized MTA for all three uses of MPU-3200, MPU-5400 and MPU-8470 with mounted machines and implements are given in Table. 1.

Table 1

In justifying and calculating the MPU transmission, it is of particular interest to determine the energy characteristics combining mechanic and analytic and hydrodynamic analytical constructions in both deterministic and probabilistic execution.

Let us consider the hardest working conditions of the MPU in the traction and drive mode, when the MTA on the basis of the MPU produces not only operations with trailed and mounted implements, but also threshing spiked cereals with a trailed non-motorized combine harvester or harvesting corn for silage using a mounted adapter.

We will write the determined ratio of energy consumption in the expanded form for MTA on the basis of MPU-5400 (f. 1):

$$
N_{\text{eff}} = \Delta p_{21} B_{21} \cdot \frac{\varrho_{\text{mov}}}{75} + m_{5400} \cdot f_{\text{roll}} \cdot \frac{\varrho_{\text{mov}}}{75} + m_{\text{harv}} \cdot f_{\text{roll,harv}} \cdot \frac{\varrho_{\text{mov}}}{75} +

+ m_{\text{corn}} \cdot f_{\text{roll}} \cdot \frac{\varrho_{\text{mov}}}{75} + \Delta p_{\text{harv}} B_{21} \cdot \frac{\varrho_{\text{mov}}}{75}.
$$

(1)

Here $N_{\text{eff}}$ – is the effective power providing the operation of the MTA;
if we take the whole of the right side of (1) for the energy resistance $N_{\text{mr}}$, then
The first term on the right side corresponds to the resistance energy of the disk header with width $B_{21}$ (it is the same for all working elements), which moves with the translational velocity $\vartheta_{mov}$ (it is the same for all MTAs); $\Delta p_{21}$ – specific resistance of the disk header (kgf/m): 

the second additive determines the resistance of the MPU-5400 mass to rolling ($m_{s400}$ – the operational mass of the energy source, $f_{roll_{u}}$ – the rolling factor of the track-type machine, $f_{roll_{u}} = 0,08$); 

the third additive reflects the cost of energy for rolling the total operating weight of a non-motor combine ($m_{harv}$ – mass of the combine, $f_{roll_{u}}$ – rolling ratio, $f_{roll_{u}} = 0,12$); 

the fourth additive corresponds to the amount of energy spent on rolling the mass of grain $m_{corn}$ in the trailer bunker; 

the last additive estimates the energy input to the technological process of the combine itself, the value of which depends on the yield of the plant mass, the per-second feed $q$ (kg/s) of it into the grinder at the corresponding translational speed $\vartheta_{mov}$; can be calculated on the basis of the value of the specific energy consumption for threshing, which we estimate to be equal to $17 \frac{kW}{kg \cdot s}$, under the given conditions.

Then $N_{tmr}$ after the substitutions and calculations will be 190.7 kW.

Now let us introduce the hydraulic drive, keeping in mind that the moment $M_{eff}$, created by the hydraulic drive to supply the energy to MPU-5400 all its mounted, trailed and driven machines and implements, obeys the relation $M_{eff} \geq M_{trm}$, where $M_{trm}$ – is the total moment of resistance (f. 2).

$$M_{eff} = \frac{N_{eff} \cdot 9449}{n} = \frac{190.7 \cdot 9449}{1900} = 948.4 \; N \cdot m$$

(2)

(the relations correspond to hydrodynamic regularities [10]);

$n_{gm}$ – frequency of rotation of the ICE shaft, to the value of which the frequency of rotation of the drive motor is given).

But the value of $M_{eff}$, developed by the hydraulic drive, will be (f. 3)

$$M_{eff} = \frac{1.56 \cdot \vartheta_{gm} \cdot \Delta p \cdot \eta_{mh}}{100}$$

(3)

From here

$$\vartheta_{gp} = \frac{948.4 \cdot 100}{1.56 \cdot 350 \cdot 0.95} = 182.8 \; sm^3.$$ 

(4)

At $\Delta p = 350 \; kgf/sm^2$ the flow rate $Q$ of the working fluid in accordance with [10] is (f. 5):

$$Q = \frac{\vartheta_{gm} \cdot n_{gm}}{1000 \cdot \eta_{mh}} = \frac{182.8 \cdot 1900}{1000 \cdot 0.95} = 365.6 \; l/min.$$ 

(5)

Then $N_{hp}$ – the total power consumed by the hydraulic drive – will amount to (f. 6):
Finally, we determine the mathematical expectation of the drive (consumed power [11], hereinafter calculations on analytical constructions of Prof. L. Ye. Ageyev (f. 7-9).

\[ N_{ip} = \frac{Q \cdot \Delta p}{612 \cdot \eta} = \frac{365.6 \cdot 350}{612 \cdot 0.9} = 232.3 \text{ kW}. \]  

(6)

Hence the mathematical expectation \( M(N_e) \) of the power will be (f. 10):

\[ M(N_e) = \lambda_{N_e} \cdot N_e, \]  

(10)

Here \( \lambda_{N_e} = 0.89 \) (the degree of ICE loading) at \( \sigma_{N_e} = \frac{232.3 \cdot 0.2}{3} = 15.5 \text{ kW}. \)

Then (f. 11)

\[ N_{ip} = M(N_e) = 232.3 \cdot 0.89 + 3\sigma_{N_e} = 252 \text{ kW}. \]  

(11)

We take the power of the installed ICE 265 kW (or 360 hp.).

Thus, the power of the ICE in the MPU-5400 drive and other types of new mobile power units with a hydraulic drive is calculated. According to the data obtained, it is already possible to perform a detailed calculation of the hydrostatic transmission and engage in the design of the hydraulic drive as a whole.

The economic efficiency of the use of new MPUs (of the fifth generation) was calculated in relation to those conditions that were determined by the operational platforms using methodology b. VNIPTIMESKH and ACHII. All the new MPUs participating in the technological processes were equipped with working bodies, machines and tools forming multi-process MTAs (in accordance with Table 1 with reference to MPU-3200, MPU-5400 and MPU-8470).

As a basis for comparison, traditional technologies and traditional MTAs based on fourth generation tractors were used: for the first variant (crop rotation applied to the PF area of 960 hectares) – based on the new ATM-3180 wheeled tractor (class 3, 132 kW); for the second variant – a crop rotation of 2250 hectares for agricultural organizations – on the basis of a new crawler tractor "Ruslan" of class 6 with a capacity of 246 kW; the third option – for service technological operations – for the same "Ruslan", because we do not produce more powerful agricultural tractors in Russia. If the duration of the original works was chosen as the evaluation criterion in the MTA synthesis stage, then at the final stage of the study, the effectiveness evaluations were carried out in accordance with the criteria for the type of discounted income adopted for such work.

The calculated data for the third variant (as an example) are given in Table. 2.

Table 2
Table 2 shows that the number of working hours for four operations performed by multi-process MTAs based on the MPU-8470 was 1402.3 hours. The same work was performed by traditional MTAs based on the fourth-generation caterpillar tractor in six operations, spending 3229.1 h at the same time. The new complex of machines, combined into multiprocess MTAs based on MPU-8470, thus ensured a reduction in the duration of work by 2.3 times, which confirms the high technical and operational efficiency of innovative technology and equipment. Appropriate, though not so high, indicators were obtained for two other innovative machine complexes. Thus, multiprocess MTAs based on the MPU-3200 in wheeled and, in some operations, caterpillar performance (with replaceable running gear) allowed to reduce the estimated duration of original operations to 831.7 h against 1143.8 h in traditional technology based on the fourth generation tractor ATM-3180, i.e. by 1.38 times.

The second variant, which was analyzed using the fifth generation MPU-5400 mobile power unit in innovative MTAs, provided the total duration of multiprocessing operations for 1408.5 hours, reducing it compared to the traditional technology based on the fourth generation Ruslan tractor – 2155.2 hours – 1.53 times.

Thus, in the mass work in agricultural production, labor costs from the use of innovative MTAs based on the MPU of the fifth generation will be reduced by 1.3 .. 1.5 times. In general, this is a fairly significant reduction in labor costs.

The calculated values of the mathematical expectation of the hourly performance of \( M(\eta) \) multiprocess MTAs based on MPU of the fifth generation were determined by the dependence (f. 12, 13):

\[
M(W) = c_1 M(N_e),
\]

where

\[
c_1 = 0.36 \eta_m \tau \frac{1}{k_a},
\]

in (f.13) \( \eta_m \) – is the tractive efficiency;
\( \tau \) – is the degree of use of the operating time of the MTA;
\( 1/k_a \) – is the specific resistance of MTA, kN/m.

Table 3 shows the values of \( M(\eta) \) for the three MPU classes considered for \( \eta = 0.6, \tau = 0.7, 1/k_a = 11\ldots13.3 \) kW/t.

Table 3

The proposed mobile energy of the *fifth generation* for agriculture has much greater opportunities to reduce the time required to implement technological processes in the cultivation of field crops. At the same time, real ways of ecological balance of technogenic processes in grain production were identified, which include the reduction of the number of driveways across the field due to the creation of multiprocess MTAs, the use of a replacement chassis. It is not a question of adapting existing and current agricultural tractors of the fourth generation to multiprocessing operations, for example, by a set of a line loop of tools and machines, extremely inconvenient in operation with simultaneous loss of productivity; it is about the *development of special machines of a new generation* that can, generally speaking, provide synthesis of mobile aggregates quite comfortably, and at the same time they are "genetically" adapted to multi-process operations. At the same time, a radical modernization of transmissions in the direction of steplessness is envisaged; the sky is the limit concerning the wide opportunities for MTA automation (although this problem could be solved for a
fourth-generation tractor much earlier, given that one of the authors of this work participated in creating a prototype of a real fifth-generation class 3 MPU with a hydrodrive 30 years ago).

The same applies to the replacement caterpillar chassis, which was created in the b. VNIPTIMESKH (Zernograd) also about 30 years ago. But nevertheless, now the problem has shifted to the real plane of its solution, and the technical documentation for the fifth-generation MPU is being developed.

4. Conclusions

1. Modern tractors of the fourth generation have reached such a high power-to-weight ratio in their development that their loading requires synthesis of rather bulky trailed and mounted complex structures, which reduces productivity to some extent. Heavy energy resources have a negative impact on the soil, contribute to a significant decrease in yield, worsen the structure of the arable layer, destroy soil aggregates and create additional conditions for wind erosion.

2. The developed family of mobile power units of the fifth generation of classes 3, 5 ... 6 and 8 with a power from 180 to 350 kW and weight from 7600 to 14500 kg are equipped with two unified mounted systems, two independent PTO, a stepless drive transmission, a replaceable caterpillar chassis; the so-called multiprocess MTA can be synthesized on their basis, that ensure the ecological balance of the technogenic interaction of the MTA with the production layer in agroecosystems and reduce the duration of field operations both in individual processes and in zonal rotation as a whole.

3. The use of a stepless transmission allows using the full power of the MPU energy unit at any point of the MTA’s trajectory to the max, opens up wide possibilities for automation of dynamic systems in order to increase the stability of the output parameters of technological processes.

4. The use of the lightweight crawler tracker on MPUs of classes 3 and 5 with a mass of not more than 11,000 kg, with the simultaneous removal of machines with larger masses in the wheeled version from field works, effectively removes the problem of negative man-made impact on the production layers of the soil.

5. Carrying out design and calculation work for the creation of a fifth-generation MPU with stepless hydraulic drive of the transmission to improve accuracy implies the introduction of hydrodynamic regularities and the apparatus of random functions into the computational algorithms.

References

1. Rusanov, V.A. The problem of soil re-consolidation and effective ways to solve it, Moscow: Kolos (1998).


Andrey Y. Nesmiyan is Candidate of Technical Sciences, Associate Professor. In 1998 he graduated with honors from the FGOU VPO ACHAA (Zernograd, Rostov region, Russia), majoring in "Mechanization of Agriculture". Since 2002, he started working at the same department in the department "Agricultural machines", which in 2007 was transformed into the chair "Mechanization of plant growing". In 2003 he was awarded the scientific degree of candidate of technical sciences, in 2007 - the academic title of associate professor. From 2011 to 2016 years. - Head of the Department of Mechanization of Plant Production. Since 2016 - Associate Professor of the Department of "Technologies and Means of Mechanization of the Agro-Industrial Complex" of the Azov-Chernomorsk Engineering Institute of the FGBOU VO Donskoy State University (Zernograd, Rostov Region, Russia), since 2017 - Professor of the same department. The author (co-author) of more than 180 scientific works, including two monographs, 77 patents for inventions and utility models and 30 articles published in the editions of the VAK list.

Sergey L. Nikitchenko is Candidate of Technical Sciences, Associate Professor. Head of the department "Technical service in the agro-industrial complex" of the Azov-Chernomorsk engineering institute FGBOU V "Donskoy GAU" in Zernograd. In 1996 he graduated from FGOU VPO ACHAA (Zernograd, Rostov region, Russia), majoring in "Mechanization of Agriculture". From 1999 to 2005 Assistant and Associate Professor of the Department of Theoretical Mechanics of ACHAA, taught the disciplines of hydraulics, theoretical mechanics, the theory of mechanisms and machines. In 2001 he defended his thesis on "Improving the efficiency of using energy-saturated tractors with a reduced technical resource". In 2005-2006, worked as a logistics operator in the field of trucking and goods circulation in the group of companies "YUGTEHKOMPLEKTI" (Rostov-on-Don). Since 2007, the senior lecturer of the Department of Mechanization of Plant Production, and since 2012 the Head of the Department "Technical Service in the Agroindustrial Complex". The author of two monographs, 67 scientific articles, including 19 from the list of VAK, and 12 educational and methodical publications. It has 8 certificates on state registration of software, 1 patent for utility model of the Russian Federation.

Vladimir V. Shchirov in 1999 he graduated from the FGOU VPO ACHAA (Zernograd, Rostov region, Russia), majoring in "Mechanization of Agriculture". Since 2002 - engineer-designer of the Institute of Agroengineering Problems (FGOU VPO ACHAA), since 2012 - Chief Designer of the IAP. Since 2016 - the head of the scientific and technical project of the "Engineering and Transfer Center" of the Azov-Black Sea Engineering Institute of the FGBOU VO Donskoy GAU (Zernograd, Rostov Region, Russia). Author (co-author) 5 articles of different levels, 12 patents for inventions and utility models.

Yuriy G. Kormil'tsev graduated in 1991 with honors from the Taganrog Radio Engineering Institute. V.D. Kalmykova (Taganrog, Rostov Region, Russia), specialty "Electroacoustics and ultrasonic sound equipment". Since 1991, he began working as a design engineer in the department of the Chief Designer of the Priboy plant in Taganrog. In 1994 he graduated from the special faculty for the retraining of the staff of the Taganrog State Radio Engineering University, specializing in "Organization of entrepreneurial activities" with qualification "Manager-Economist". In 1995 he organized and headed the enterprise for the production of spare parts for agricultural machinery in the structure of which the design department for the improvement of individual parts and units of agricultural machinery and the development of CD for new complete equipment was created. Since 2001 - General Director of Research and Production Tensor-T Research and Development LLC. Author (co-author) 10 patents for inventions and utility models.
<table>
<thead>
<tr>
<th>Crop rotation 960 ha (PF)</th>
<th>Crop rotation 2250 ha (AS, CAE, APC)</th>
<th>Technological service of MTS type</th>
</tr>
</thead>
<tbody>
<tr>
<td>The name of the operation</td>
<td>MTA composition: MPU-3200</td>
<td>MTA composition: MPU-5400</td>
</tr>
<tr>
<td>Pre-sowing tillage with sowing of spiked cereals</td>
<td>Harvesting winter crops with primary field processing</td>
<td>Harrow disk medium + MPU-5400 + harvester trailed non-motorized</td>
</tr>
<tr>
<td>Presowing tillage with simultaneous sowing of tilled</td>
<td>Soil preparation for sowing with corn sowing</td>
<td>Cultivator + MPU + tilled mounted seeding-machine</td>
</tr>
<tr>
<td>Harvesting of corn for silage with preparation of soil for sowing of winter crops</td>
<td>Harvesting of corn in cobs with preparation of soil for sowing of winter crops (according to non-steam predecessors)</td>
<td>Adapter cob sweeper mounted + MPU + AKM-4</td>
</tr>
<tr>
<td>Harvesting of corn for silage with preparation of soil for sowing of winter crops (for non-steam predecessors)</td>
<td>Primary soil tillage with leveling</td>
<td>Cultivator + MPU + AKM-8</td>
</tr>
<tr>
<td>Dump plowing - basic sow tillage</td>
<td>AKM-6 + MPU + harvester trailed</td>
<td>Disk header + MPU + reversible plow 12-hull</td>
</tr>
<tr>
<td>Preparation of soil for sowing with subsoiling</td>
<td>Harrow medium + MPU + harvester trailed</td>
<td>Combing adapter + MPU + mounted MSU with cleaning + towed trailer</td>
</tr>
</tbody>
</table>

---

**Table 1.** Complex operations and composition of multi-process MTA based on MPU of the fifth generation.
<table>
<thead>
<tr>
<th>№</th>
<th>The general name of the operation</th>
<th>Name of the transition</th>
<th>Scope of work, ha</th>
<th>Acquisition of operations; MTA; parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Traditional (fourth generation)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Innovative (fifth generation)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Soil-cultivating operation</td>
<td>Surface tillage of soil</td>
<td>400</td>
<td>MTA composition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Subsoilng</td>
<td></td>
<td>MPU-8450 + medium tiller + deep tiller</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Soil-cultivating operation</td>
<td>Subsoilng with soil leveling</td>
<td>750</td>
<td>MPU-8450 + disk header on the front hinge + deep tiller</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Soil-cultivating operation: soil preparation for sowing</td>
<td>Cultivation</td>
<td>1200</td>
<td>MPU-8450 + cultivator + AKM-6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Soil-cultivating operation: moldboard processing</td>
<td>Main moldboard processin g</td>
<td>1000</td>
<td>MPU-8450 + reversibl e plow 12-hull + disk header</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Harvesting of spiked cereals with</td>
<td>Harvesting of spiked cereals with</td>
<td>1200</td>
<td>MPU-8450 + mounted combing adapter</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6 Harvesting corn for silage  800 «Don-680»  4,0 8,0 2,5 312,5  6 10 4, 166, 6
Mowing with grinding and loading into a container
Soil preparation for sowing of winter crops
«Ruslan 6,0 10,0 4,8 166,6 + AKM-6
In all operations, the fifth generation's innovativeness can be seen (according to our innovation scheme)

<table>
<thead>
<tr>
<th>MPU: conventional brand</th>
<th>τ</th>
<th>η</th>
<th>k_ν, kW/t</th>
<th>M(N_ν), kW</th>
<th>M(W_ν), ha/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPU-3200</td>
<td>0,7</td>
<td>0,6</td>
<td>11,0</td>
<td>169,0</td>
<td>2,3</td>
</tr>
<tr>
<td>MPU-5400</td>
<td>0,7</td>
<td>0,6</td>
<td>12,0</td>
<td>252,0</td>
<td>3,17</td>
</tr>
<tr>
<td>MPU-8470</td>
<td>0,65</td>
<td>13,3</td>
<td>320,0</td>
<td>3,94</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Mathematical expectations of the hourly performance of multiprocess MTAs based on the fifth-generation MPU.
a) for nonmoldboard basic soil tillage

b) in caterpillar performance (changeable chassis)

Figure 1. Mobile power unit MPU-3200 of cl. 3 with a power of 180 kW
Figure 2. Mobile Power Unit MPU-5400 of cl. 5 with a power of 280 kW with mounted tools.
Figure 3. Grain-harvesting and soil-cultivating MTA on the basis of MPU-5400: the mounted adapter for postharvest closing of a moisture; trailed non-motor combine with a capacity of 5 ... 6 kg/s axial-rotary with a transverse arrangement of threshing-separating devices; tank grain trailer
Figure 4. Forage-soil cultivating MTA on the basis of wheel MPU-5400 of class 5: mounted silage harvester for harvesting and chopping maize for silage; AKM aggregate for soil preparation for sowing of winter crops on non-steam predecessor trailed
**Figure 5.** Tillage caterpillar MTA; MPU of class 5 (model in scale 1:12)

**Figure 6.** Mobile power unit MPU-8470 of class 8 with a power of 380 kW with trailed 12-hull reverse plow and hinged disk header for post-harvest moisture closure in the production layer of the soil
Figure 7. Mobile power unit MPU-8470 with mounted disk header and trailed deep tiller (chisel plow)
Figure 8. MPU-8470 with a trailed high-performance, non-motorized combine harvester with a transverse axial-rotor threshing separating device with a throughput capacity of 8 ... 8.5 kg/s with a trailer hopper and a disk header to cover moisture