Determining the workload of the machine and tractor fleet maintenance service in agriculture using the scheduling method

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Abstract. The efficient operation of agricultural machinery depends on the rational organisation of its maintenance. The most systematic research on the technical service of agricultural machinery has been carried out in GosNITI. An integrated maintenance and repair system for agricultural machinery (TORSELHOZ) has been developed. But this system is currently in contradiction with the emerging trend of declining agricultural machinery production, the expansion of more reliable foreign machines than domestic ones on the domestic market and the lack of qualified staff of machine operators. Machine reliability indicators determine the amount of repair and maintenance work. In its turn, these volumes of work are the initial characteristics for the formation of a repair and maintenance base for the technical service of agricultural machinery. The dealer system, which is very important, is the link between the machine manufacturer and the farmer. However, the dealer service cannot meet such challenges due to a lack of logistical and financial resources, as well as a de facto lack of a service user. Therefore, much of the maintenance and repair work on machinery and tractor fleets must be organised on the farm, with the adopted maintenance organisation system forming a major part of the efficiency of this system. The scheduling method of tractor maintenance takes into account the specifics of agricultural production and ensures timely and complete maintenance. Research has shown that the efficiency of maintenance organisation is mainly influenced by the arable area, the class of personnel in the system, the energy capacity of the farm, the availability of mechanics and the uneven load of MTP over the periods. The main points of the method of organising maintenance according to the scheduling system are defined.

1 Introduction

In agricultural production processes, combines, tractors and the agricultural machinery connected to them are the main means of carrying out technological operations. This equipment is a key means of production for the entire agricultural sector of the region and must meet increasing production requirements. In order to maintain machinery in a

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serviceable condition, it is necessary to improve the organisation of technical service, which is dictated not only by changes in the structure of MTP, the ageing fleet of machines, and the requirements of Article 215 of the Labour Code, but also by the crisis state of much of the necessary material and technical base for the maintenance and repair of the machine and tractor fleet [1-2].

2 Materials and methods

The main research methods used were methods of data collection and statistical processing under machine-tractor fleet conditions, sources of literature data with an assessment of the comparability of conditions, and data from experiments conducted, mathematical modelling methods were applied to process the experimental data.

3 Results and Discussion

Research has shown that the particularities of the maintenance system of a specific farm depend on the following conditions: F – farm's arable land, ha; K_T – the rate at which the area is ploughed:

$$K_T = \frac{F}{F_1}, \tag{1}$$

Where, F1 - total area of the farm, ha; e – tractor work density, t.e.g. ha/ha of arable land:

$$e = \frac{W_{sum}}{F} \tag{2}$$

W_{sum} – total annual operating hours of tractors, tth. ha; ε – farm machinery, kW/100 ha of arable land.

$$\varepsilon = \frac{100\sum iN_i}{F} \tag{3}$$

Where $\sum iN_i$ – total power of the tractors used, kW; ξ – uneven loading of tractors by V-periods of use:

$$\xi = \frac{W_v}{W_{sum}} \tag{4}$$

Where W_v – tractor operating hours for the V-period in question; pi – of compactness of the area, equal to the average radius of the farm area, km; X4 – the number of machine operators per 100 hectares of arable land; X5 – grade of staff.

Investigating the conditions for organising maintenance of MTPs in different sizes and mentioned characteristics, using multivariate models, we found that the above-mentioned factors influence the choice of forms of organisation for the maintenance of machines as follows (Table 1).

Table 1. Significance of factors influencing the choice of forms of maintenance.

Indicator weighting	**F**	**KT**	**e**	**ε**	**ξ**	**Pi**	**X4**	**X5**
Pxi, %	39.1	5.3	2.8	9.7	7.6	3.1	7.3	25.2

As it can be seen, on efficiency of organization of technical maintenance have influence first of all on area of arable land PF=39.1%, class of personnel in technical maintenance system PX5=25.2%, power supply of farm Pε=9.7%, supply with mechanics PX4=7.3% and irregularity of loading of MTP for periods Pξ=7.6%.

It can therefore be concluded that it is advantageous to carry out maintenance where there are shorter travel distances (F terrain) and to locate maintenance facilities where the most qualified maintenance personnel are concentrated. In order to achieve the greatest effect, maintenance and repair of machinery should be carried out during non-stressed periods of use, according to the principle of scheduling [3-4]. Machine operators have been repairing tractors in the winter when the equipment is not in use for a long time. Things look different with the maintenance services so far.

The scheduling method of tractor maintenance takes into account the specifics of agricultural production and ensures timely and complete maintenance [5].

Looking at the graph of machine use (figure 1), it can be stated that during the periods of May, July, September, October up to 60-80% of the field work is performed. During these busy periods of fieldwork, when there is a lack of qualified personnel, there are also problems with maintenance during tractor operation, because according to the current maintenance system, the higher the running hours, the more maintenance work needs to be performed. Based on operating hours, it should be possible to perform during busy periods of fieldwork and major volumes of complex maintenance 2 and 3, which are time-consuming and resource-intensive. This is one of the main contradictions in the current planning and prevention system [6- 7].

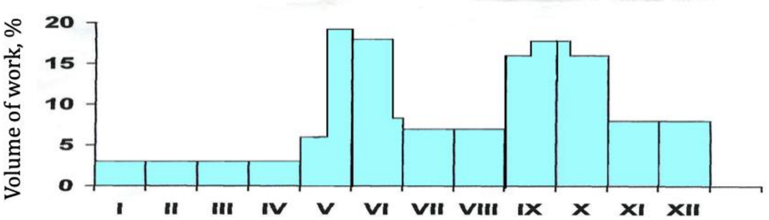

Fig. 1. Graph of machine use.

In this case, the labour intensity of maintenance 2 ranges from 5.3-11.6 and the labour intensity of maintenance 3 is 17-28 man-hours.

Table 2 shows the labour intensity of the main tractor brands on some farms in the Omsk region.

Table 2. Tractor maintenance labour intensity, man-hours.[2].

Type of maintenance	**MTZ - 82**	**J. Deere**	**К – 700**	**Landini**	**T-150**	**T-170**
MRO - 1	2.1	2.4	2.5	1.7	2.4	1.8
MRO - 2	7.7	5.3	11.6	6.4	6.5	6.9
MRO - 3	22	23	28	17	29	19
Seasonal MROs	11	14.5	27.5	9	16.5	11

The problem arises: "either work or do maintenance".

We investigated the impact of individual MRO operations on the serviceability of components, in particular K-700 and K-701 tractors, and found that there are limiting operations that need to be performed just in time, and there are operations that can be moved out of the busy period of fieldwork without any damage, or otherwise, MRO can be performed before the busy period of fieldwork, that is, according to the principle of calendar scheduling.

The main points of this method are as follows:

- We make MRO-2 more complicated, we carry out MRO-3 with the use of diagnostic tools, as a result we create a "reserve" of machine uptime.
- Maintenance of machinery is performed according to a strictly scheduled schedule, prior to major agricultural work. The timing of maintenance operations is based on the prevailing farm-specific agronomic schedules and the normative frequency of maintenance operations.
- Only tractors that have previously been in operation are to be serviced (it is assumed that tractors that have not been in operation have already been serviced).
- A special team is formed to maintain the machinery within the calendar timeframe, consisting of master adjusters, a fitter, an electrical technician, a diagnostician. The number of units depends on the volume of work.
- In order to reduce tractor and combine harvester downtime and improve the quality of their maintenance, replacement sets of filter elements, nozzles, sensors, etc. are used, which are prepared in advance in specialised areas. These kits allow you to avoid maintenance and failure repair work such as cleaning and washing filters, repairing and adjusting individual tractor assemblies, increasing the quality of service and ensuring proper quality control.

In order to organise maintenance, the engineering service must fulfil the following comprehensive measures [8]:

- Form a brigade and determine its size.
- Determine the location of maintenance, both in summer and winter.
- Determine the order of arrival of machinery based on daily output.
- Organise sites for the preparation of replacement filter element kits and spare parts.
- Create an adequate supply of oils.
- Organise quality control of the maintenance service, develop an inspection schedule.
- Develop terms of moral and material incentives for the quality of maintenance and readiness of machinery.
- Draw up maintenance charts (sequence of operations and diagnostics).

A maintenance schedule (Table 3) is prepared for the farm conditions. The input information is the prevailing agronomic deadlines for the main agricultural work, the number of tractors in operation and their load during these periods.

Table 3. Tractor maintenance schedule for the farm.

Indicators	**Months of the year**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Timeframes for MROs	-	-	1-30	1-5	-	2-7	-	-	5-10	-	1-27	-
Number of maintenance intervals:												
MRO 2	-	-	-	7	-	5	-	-	6	-	4	-
MRO 3	-	-	-	1	-	2	-	-	-	-	1	-
SERVICE STATION	-	-	45	-	-	-	-	-	-	-	45	-

Based on an analysis of statistical information over the last 3-4 years, the number of tractors in operation and the amount of work they do are established. Based on the average number of working tractors and their load, determine the number of maintenance operations by type and the total amount of maintenance work to be performed before each period of agricultural work.

The number of MROs (ni) in the planning period (operating hours Qn) is determined:

$$n_i = \frac{Q_i + Q_n}{t_i} - n_{i+1} \tag{5}$$

Where Q_i – the operating time since the last maintenance of the i-th type; t_i – frequency of maintenance of the i-th type; n_{i+1} – frequency of maintenance of the i-th type.

$$n_3 = \frac{Q_3 + Q_n}{t_3}; \quad n_2 = \frac{Q_2 + Q_n}{t_2} - n_3; \quad n_1 = \frac{Q_1 + Q_n}{t_1} - n_3 - n_2 \tag{6}$$

If Q_i it is not known, determine it using the formula:

$$Q_i = Q_н - \gamma \cdot t_i \tag{7}$$

Where Q_n – operating time from the start of operation:

$$\gamma = \frac{Q_н}{t_i} \tag{8}$$

Let $Q_н$ =1800 litre, t_i =500, $\gamma = \frac{1800}{500} = 3{,}6$, take γ =3.

Then Q_i =1800-3·500 = 300 litre, the number of seasonal maintenance services - twice a year.

Maintenance labour intensity $\sum T_i$

$$\sum_j^m \sum_i^n T_{ij} = \sum_j^m n_{1j} \cdot T_{1j} + \sum_j^m n_{2i} \cdot T_{2i} + \sum_j^m n_{3i} \cdot T_{3j} + \sum_j^m n_{CTOi} \cdot T_{CTOj} \tag{9}$$

Specific labour requirements for maintenance:

$$T_{удij} = \frac{\sum_j^m \sum_i^n T_{ij}}{W} \tag{10}$$

Where W – the amount of work carried out in tonnes of fuel.

Number of workers (m) based on working hours Φ_P :

$$m = \frac{\sum_{j}^{m} \sum_{i}^{n} T_{ij}}{\Phi_P} \tag{11}$$

Working time fund:

$$\Phi_P = Д_P \cdot T_P \cdot \tau \tag{12}$$

Where τ - duty cycle.

τ – depends on the location of the MRO and may be in the range of τ =0.55-0.85. Higher value when maintenance is performed in stationary conditions, lower value in the field.

The number of calendar days for tractor maintenance for each fieldwork period is determined by the formula:

$$n_\partial = \frac{\Sigma T_{TO}}{n_M \cdot \tau_{un} \cdot T_{CM}} \tag{13}$$

The centre of the maintenance facilities can be the central farmstead or the production unit. For its determination, the average radius of the area to be served must be calculated, and then the economically feasible distances for transporting machines for service must be determined [9]. They will depend on the period of tractor use (cost per hour of downtime), road conditions (speed of travel), etc. [10-11].

The radius of the service area can be assumed as the radius of inertia of the flat shape in relation to the location of the logistics base for maintenance and current repair [12-13].

Radius of inertia ρ of a flat shape S_1 in relation to the pole(μ):

$$\rho = \sqrt{\frac{У_ш}{S_1}} \tag{14}$$

Where Уш – polar moment of inertia.

All forms of the farmland can in principle be reduced to the shape of a circle or an ellipse. Thus for a circle:

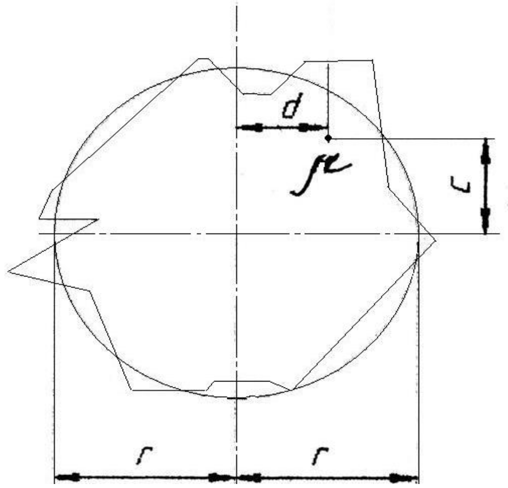

Fig. 2. Shape of the farm area reduced to the shape of a circle.

$$R = \gamma\sqrt{d^2 + c^2 + \frac{r^2}{2}}, \tag{15}$$

Where γ – the road curvature factor can be found from the empirical formula:

$$\gamma = 1 + 0,53K_T^{2,3} \tag{16}$$

Where KT – area rate.
Let c and d be 5km, r be 20km, and KT =0.5, then:

$$\gamma = 1 + 0,53 \cdot 0,5^{2,3} \cong 1,13 \tag{17}$$

And the radius of the farm area is:

$$r_x = \sqrt{25 + 25 + \frac{10^2}{2}} = 1,13\sqrt{50 + 50} = 11,3 \tag{18}$$

For an ellipse:

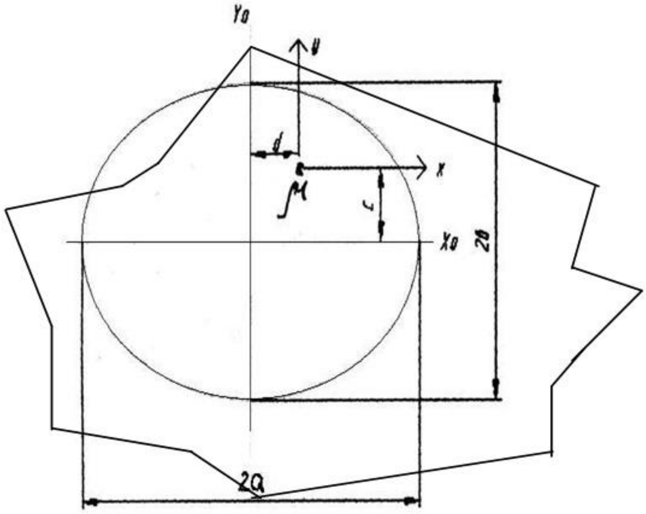

Fig. 3. Shape of the farm area reduced to an ellipse.

$$z = \sqrt{\frac{a^2 + b^2}{4} + c^2 + d^2} \tag{19}$$

Ploughing ratio 0.2-coefficient.

Road curvature-1.16; Krt-0.3; Kid-1.19; 0.4-1.22; 0.5-1.25; 0.6-1.28; 0.7-1.31; 0.8-1.31.

To calculate the need for performers, when using a mobile unit, the possible daily mileage (L km) of the unit on the truck should be taken into account:

$$L_{aTTO} = 15{,}1M_{gv} + 2{,}3R + 3{,}37r - 14{,}5 \tag{20}$$

Where Mgv – number of applications per day in the v-th period; R – distance from the production unit (concentration of tractors) to the central farmstead (concentration of maintenance equipment), km; r – average radius of the production unit, km.

If the MRO facilities are concentrated on the production unit, then R=0.

To determine the permissible transport radius of tractors for maintenance in the function (14) [14-15] we take the capital costs of establishing a repair and maintenance base to be zero (no funds and no service user) and, solving it with respect to R, we obtain the permissible distances of tractor trips to a fixed location (the central farmstead) for maintenance (table 4).

Table 4. Permissible driving distances of tractors to a stationary service station.

Tractor brand	**Permissible distance to a fixed point, km**		
	MRO number		
	No. 1	**No. 2**	**No. 3 and seasonal**
K-744	7.5	15	60
MTW	10	31	80

By comparing the average radius of the farm area with the values allowed (Table 4), a decision on the location of the maintenance services was made. The quality of maintenance and diagnostics has been checked on the scheduled operations that have the greatest impact on the tractor's uptime. The weight of the operations must be borne in mind: for the engine, 68%; for the gearbox, 24%; for the drive axle, 7.0%; and for others, 1%.

4 Conclusion

The following conclusions can be drawn from the research:

- The efficiency of maintenance organisation is mainly influenced by the area of arable land PF = 39.1%, class of personnel in maintenance system PX5 = 25.2%, energy equipment of the farm $P\varepsilon$ = 9.7%, supply with mechanics PX4 = 7.3% and unevenness of MTP loading on periods $P\xi$ = 7.6%.
- Identified the main provisions for the method of scheduling for the conditions of use of the machine-tractor fleet of farms in the Omsk region.
- The quality of maintenance can be judged more or less fully by the maintenance operations performed on the engine.
- The quality of maintenance can be assessed by the following criteria: timely oil change, level and appropriateness of grades; replacement of filter elements; tensioning of belts and chains; adjustment of fuel pump and injectors; battery charge level and electrolyte density; condition of cylinder heads; condition of hydraulic system.

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