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Concept for the formation of technical service of agricultural machinery in Western Siberia

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Abstract. The service concept for agricultural machinery can only be viable if priority is given to the use of machines in agricultural work. The main contradiction in the maintenance and machine usage system is the overlapping timing: the higher the operating time, the more maintenance work needs to be done. The specifics of determining maintenance load are that current issues and trends in machine maintenance need to be taken into account. They consist in the fact that the technical and financial basis for the formation of an effective specialised service system is now virtually non-existent on the one hand, and the virtual absence of a service consumer because of the insufficient profitability of agricultural enterprises on the other. For the time being, therefore, machinery will have to be repaired and maintained mainly by the farms themselves by replacing worn units and parts with new or second-hand ones in the workshops of the farms. How to make this work more effectively? In the research, the use of agricultural machinery has been considered. Proposed and substantiated the concept of technical service formation at the enterprises of agroindustrial complex of Western Siberia. The main advantages of the proposed agricultural equipment maintenance system concept are discussed.

1 Introduction

The main feature of the use of agricultural machinery is the uneven amount of agricultural work carried out at different times during the year. Table 1 shows the unevenness of the amount of agricultural work performed in different climatic zones. Table 1 shows that the busy period in the Siberian zone (usually spring or autumn) accounts for a quarter of the annual volume of mechanised work. During this period, when a large amount of fieldwork needs to be completed within a short time frame, unproductive machine downtime for maintenance, repair and fault clearance, which should be reduced to a minimum, is a limiting factor.

But during busy periods, when the volume of mechanised work increases by a factor of 3 to 5 compared to the annual average, maintenance work increases in proportion to the number of hours worked. And the current maintenance concept requires strict observance of the frequency of repair and maintenance actions, regardless of the need to perform

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agricultural work [1-2]. With labour shortages, preventive maintenance works are generally not performed, the level of technical condition of machines is reduced, the number of failures and faults increases. Productivity and machine hours are declining and the cost of agricultural work is rising [3]. This is when the greatest losses from equipment downtime occur, both from under- and direct yield losses, and here the maintenance system must ensure that the work is performed with the best possible machine uptime and durability. As can be seen, there is an insoluble contradiction between the use of machines and their existing service system. Although this system gives priority to the use of machines in agricultural work.

Table 1. Monthly workload, % of annual.

Period	North Caucasus and southern Ukraine	Northern Kazakhstan, Siberia, Urals	Central non-chernozem zone	North West
Winter	4-5	2-4	5-6	6-7
Normal	8-10	6-12	8-12	8-10
Intense	14-16	20-26	12-14	10-12

2 Materials and methods

The main research methods used were direct observation of the conditions of use of the machine and tractor fleet, literary sources with an assessment of the comparability of conditions, as well as data from experiments performed; mathematical modelling methods and statistical processing of the results were used in the processing of the experimental data.

3 Results and Discussion

Let us attempt to estimate the complexity of maintenance operations and the intensity of their performance according to the periods of machine use.

So, analysis of failures shows that they can be divided into gradual and sudden. Gradual ones account for 65-75% of all failures on tractors [4-5]. The occurrence of these failures can be predicted because they are related to the machine's technical condition parameters and they are controllable. The occurrence of sudden failures is unfortunately difficult to predict. All failures are classified into difficulty groups one, two and three [6]. The most complex failures are those of the third group of complexity - resource failures. Repair work must be performed with possible replacement or refurbishment of major components, including the basic machine components.

Resource failures can be reduced during seasonal winter repairs. In accordance with our concept, diagnostic operations should be introduced during seasonal repairs to determine the remaining life of assemblies and units that have not been repaired and replaced, and to assess the likelihood of their occurrence during agricultural work [7]. Gradual failures in difficulty group one and two can be reduced by performing maintenance operations before the busy period of agricultural work. Here we not only reduce maintenance time during busy periods, but we also achieve a reduction in the number of failures. The studies [7-8] theoretically substantiate and prove in practice the expediency of moving complex maintenance operations 2 and 3, service stations outside the busy period of agricultural work, i.e. there is a concentration of maintenance work. It has been shown in [9-10] that the greatest cost reductions come from concentrating the repair of worn parts; followed by concentrating the repair of assemblies and sub-assemblies; complete repair of machines, running repair, maintenance and storage of machines.

Development of the rational concept of technical service should be aimed at achieving the maximum operating time and productivity of machines in periods of agricultural work (W_{max}), ensuring the highest rates of technical use (K_{timax}), providing in busy periods of machines minimum failures (n_{otkmin}) and minimum downtime for technical reasons (t_{prtmin}), and the total cost of agricultural production should also be the lowest of the possible options (z_{pmin}).

Considering the above, and the priorities of maintenance work, a modern maintenance concept (its component - structure) in relation to the main periods of agricultural work, could look as follows (table 2):

Table 2. Proposed structure of repair and maintenance actions (RMA), taking into account the peculiarities of machinery use in different periods of agricultural work.

Time of execution and type of ROV	**Feature**	**Results impacts**
Winter period, repairs	Determination of the residual life of machine components based on the results of diagnosis (MRO-3). Justified assignment of repair work.	When carrying out agricultural work during busy periods, the probability of machine failure increases. The number of complex (resource) failures of difficulty group III is reduced
A busy period of agricultural work ahead. Perform MRO-3 and MRO-2 operations to the extent of MRO-3 at the forecasted operating hours	Diagnostics, maintenance of MOT-3 and MOT-2 in the scope of MOT-3, failure rectification (FRA) of difficulty group I and II	When carrying out agricultural work during the busy period, MRO-1, UPR of complexity group I and II are carried out. Repairs, ROT of the 3rd difficulty group, ROT-2, ROT-3, STO, diagnostics are excluded.

Figure 1 shows the change in maintenance intensity over periods of machine use.

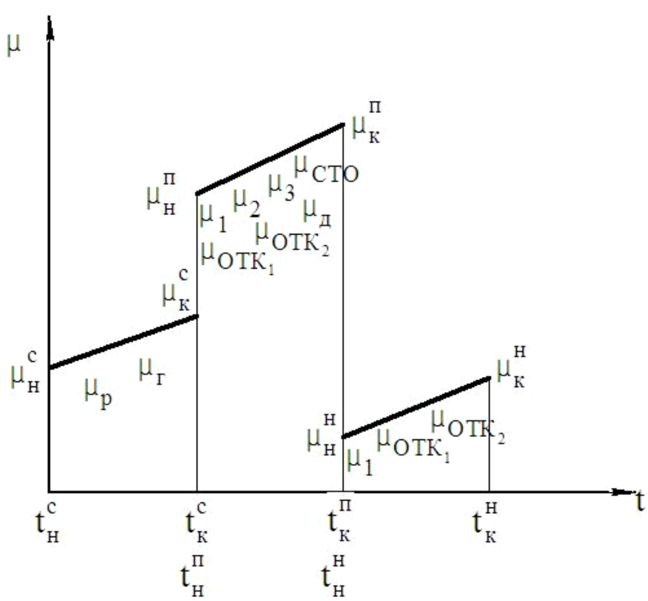

Fig. 1. Change in maintenance intensity (MRI) by machine usage period.

Cycle of machine use:

- t_c^n, t_c^k – start and end times for seasonal (winter) repairs.
- μ_h^c, μ_k^c – DER intensities at the beginning and end of seasonal maintenance.
- t_p^n, t_p^k – the time of the start and end of the ROV before a busy period of fieldwork.
- μ_N^P, μ_K^P – respectively the ROV intensities.
- t_N^k, t_K^N – the start and end times of the busy period of farm work.
- μ_N^N, μ_N^K – respectively the ROV intensities during this period.
- $\mu_1, \mu_2, \mu_3, \mu_{SS}$ – intensity of MRO-1, MRO-2, MRO-3 and workshop operations ($\mu = \frac{1}{t}$, where *t* is the average turnaround time per application).
- μ_D, μ_R – the intensity of the bidding operation and the resource operation for repairs.
- $\mu_{fail_1}, \mu_{fail_2}, \mu_{fail_3}$ – respectively the correction rates for failures of the first, second and third difficulty groups and repairs (μ_p).

The figure 1 shows that towards the end of the seasonal maintenance period, the intensity of maintenance increases slightly due to resource diagnostics. During this period, machinery is repaired and the residual life of components ($R_{residial}$) which have not been repaired or replaced during repair is determined by means of resource diagnostics. If necessary, the service life of these components and assemblies is restored.

Prior to the busy period of major agricultural work, the application diagnostics, PM2 maintenance (PM2 in our case is carried out as PM3), PM3, SERVICE, eliminate the consequences of failures and malfunctions identified. The DOM intensity increases and here it reaches its maximum value. During the period of major agricultural work, the ROV intensity decreases sharply and reaches its minimum value, as during this period only MRO-1 and rectification of failures of the first and second difficulty groups are performed.

It is also assumed that the effect of building such a system is expressed not only in the fact that the number of failures during the busy period is reduced due to preventive maintenance and seasonal repairs and elimination of the consequences of failures before the busy period, but also in the reduction of machine downtime due to increased uptime and exclusion of MRO-2 and MRO-3 not directly proportional to their reduction, but more also due to the emergence effect [10-11]. For example, the MTBF of K-700 tractors varies by a factor of 4-5 depending on the amount of maintenance work performed [12-13].

The average time to eliminate one failure is 4.82 hours (difficulty groups 1.7; 6.1; 16.6 hours respectively), and the average waiting time to eliminate one failure and transport is 23.6 hours. Across the entire maintenance level range, downtime of the tractor can range from 270 to 1,380 hours per year, or 5 times that amount. [14].

In general terms, the productivity of the machines W_f will look like in our case:

$$W_f = W_j \times k_{ti} = W_n \frac{T_p}{T_p + T_{MRO} + T_{repair}} \tag{1}$$

Where k_{ti} – duty cycle; T_p – machine operating time, h; T_{MRO} – time for performing, waiting and transporting the machine for maintenance, h; T_{repair} – time related to repairs, including the elimination of the consequences of failures and their associated waiting times, transport, h.

Given the construction of our maintenance system (Figure 1), where maintenance and repair times are reduced and machine working hours are increased, expression (1) will take the following form:

$$W_f = W_n \frac{(T_p + \Delta T_p)}{(T_p + \Delta T_p) + (T_{MRO} - \Delta T_{MRO}) + (T_{repair} - \Delta T_{repair})} \tag{2}$$

Where $\varDelta T_p$ – increased machine uptime due to the elimination of maintenance 2 and maintenance 3, and reduced downtime for troubleshooting and repair during busy periods of major agricultural work; $\varDelta T_{MRO}$ – reduced maintenance time and associated costs of time (transport, waiting time); $\varDelta T_{repair}$ – reduced time for repairs, including the elimination of the consequences of failures and the associated time costs (transport, waiting time).

Additional repair and maintenance costs are recouped by reducing downtime and losses from machine downtime and machine-tractor unit (MTU) downtime during periods of agricultural work [15-17]. Accordingly, the difference between the reduction of downtime losses and additional costs should be greater than or equal to zero:

$$Z_{\Sigma} = P_p - D_c \geq 0 \quad (3)$$

Where Z_{Σ} – cumulative effect; P_p – reducing losses from machine downtime; D_c – additional costs of repair and maintenance impacts.

In this case, P_p and D_c can be defined as:

$$P_p = P_R + P_{1,P} + P_{MRO} \quad (4)$$

$$D_c = Z_{upo} + Z_{MRO} \quad (5)$$

Where $P_R, P_{I,II}, P_{MRO}$ – reduction of downtime losses due to resource failures (difficulty group III), simple failures (difficulty groups I and II), maintenance of maintenance 3 and maintenance 2 in the scope of maintenance 3; Z_{upo}, Z_{MRO} – additional diagnostic costs in determining the remaining service life for repairs, and maintenance.

The additional costs of seasonal repairs are only the costs of diagnosing parts and assemblies that are not disassembled:

$$Z_{season} = D_R + Z_R + Z_B + Z_C + Z_O \quad (6)$$

Where D_R – the cost of resource diagnostics; Z_R, Z_B, Z_C, Z_O – costs for disassembly, refurbishment and repair, assembly, running-in and adjustment of assemblies and units.

Based on the research carried out on tractors before the period of agricultural work, carry out MOT-3 and MOT-2 to the extent of MOT-3, and during the period of agricultural work perform MOT-1. This also assumes that maintenance and troubleshooting operations use replacement kits of components and parts, which are prepared during the year when the repair and service technicians are least busy, resulting in less downtime for maintenance and troubleshooting and a higher quality of service.

4 Conclusion

The advantages of the proposed maintenance system concept are as follows:

- The new form of tractor maintenance eliminates a major contradiction that arises in agricultural work and the need to maintain machinery.
- Practically, machinery is only serviced four times during the year (including seasonal repairs) and is serviced during non-stressful periods of fieldwork when it is possible to engage a sufficient number of highly qualified personnel for a relatively short period of time, which cannot be achieved at other times.

- Quality and duration of maintenance operations is increased and reduced through more specialisation and the use of interchangeable kits.
- During busy periods, there is no need to stop tractors for maintenance, resulting in increased productivity.
- Increased reliability of machinery through improved preventative maintenance and the use of diagnostics to identify hidden faults and predict the life of machine components.
- To better utilise specialist maintenance and repair staff during off-peak periods.
- Organise the collection, storage and disposal of waste petroleum products in an environmentally friendly manner.
- The environmental and safety performance of the work is improved.
- The possibility arises of combining MRO-1 operations (due to its relatively low labour intensity) with failure repairs, which, in principle, was previously strongly discouraged. This makes it possible to formulate new requirements for a mobile maintenance unit for agricultural machinery.

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