Feasibility and efficiency of agricultural machinery maintenance

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Abstract. The greatest impact on machine uptime and performance is the timely and high-quality maintenance. The main contradiction is inherent in the system of maintenance and use of machines, in the coincidence of the timing of their performance: the more time is spent, the more maintenance operations need to be performed. As a result, during busy periods of fieldwork, to ensure high operating time, to the detriment of prevention, the mechanic has to virtually eliminate only the consequences of failures, which leads to their increase, machine productivity is reduced and operating costs increase. With the current trend of having more than one machine per operator, the operator is physically unable to perform all types of maintenance and repair work alone. Therefore, it would be advisable to transfer some of these works to specialized enterprises. The problem of increasing the reliability of tractors can also be solved by deeper specialization and intensification of maintenance operations during their transfer to nonstressed periods of fieldwork. In the work the structure of formation of technical service at the enterprises of agroindustrial complex is proposed and theoretically grounded. The main advantages of the proposed system of technical service are considered.

1. Introduction

K. Marx also emphasized, "The same means of work, i.e., the same fixed assets can be used more efficiently by increasing the time of their annual use, as well as by increasing the time and intensity of their use, without additional costs of money for fixed assets" [1]. Academician V.A. Trapeznikov also shows that intensive factors of labor productivity growth are 6.3 times more effective than expanding production assets. Increasing the quality of production produces the same consumer effect, but with costs 3-5 times less than those increasing its quantity (quality is more economical than quantity) [2]. Therefore, the increase in productivity of technics – in its more intensive use – is possible with provision of its high reliability.

2. Problem Statement

Timely maintenance is ensured if there is a 45-47% reduction in capital repair costs and a 17-21% increase in the productivity of the machine and tractor fleet. The operating time of tractors and combines is increased by 15-20%, repair costs are reduced by 10-25%, oil products consumption is reduced by 15-20%. In addition, the number of capital repairs is reduced by 38%. Non-compliance with the rules of maintenance leads to a 2.5-5 time increase in specific costs for maintaining machines in working order, reducing the time of useful work of machines [3]. Specialization and concentration of
Maintenance works contribute to their timely execution. Maintenance thus has a decisive influence on machine uptime [4].

3. Research Questions

The work [5] shows how much the timely and quality maintenance influences the indicators of reliability and inter-repair performance of tractors K-700 and K-700A and their total downtime due to technical reasons, which can vary 3-5 times. In figure 1 there is a graph of the K-700 tractors downtime change in the established annual loading during observation and maximum downtime of 1383 hours.

![Figure 1. Impact of maintenance works (A) on total downtime of K-700 tractors](image)

The most probable value of the carried out volume of works on maintenance of tractors K-700 and K-700A is now within A=0.30...0.45. At A=0.45 the operating time for failure of K-700 tractor makes 142 hours, between-repairs - 2085 hours, idle time – 406.2 hours. Improvement of maintenance service at A=0.1 entails reduction of tractor downtime by 104 hours per year. Average time of elimination of consequences of failures of the hour. The greatest time consumption is waiting and transporting – 23.6 hours.

In the opinion of some scientists to more fully and effectively use machines, it is necessary to have 135-145 mechanizers on 100 tractors [6]. But the number of mechanizers is steadily decreasing from 233 people, which accounted for 100 tractors in 1940, to 118 hours in 1980. Now there is less than one for each tractor. During the period of operation of machines - tractor stations (MTS) – there were operated tractors of Seversky - KhTP, SKhTP - NATI, S-60, and S-65 type. Rules of technical maintenance provided for 6 types of technical maintenance, 6 persons participated in maintenance (technical service - 1 and technical maintenance - 2 - 4 persons). For each hour of clean work there were 0.72 - 0.78 persons per hour of clean work. However, tractors fulfilled planned indicators [7].

With introduction of the three-dimensional system, maintenance of machinery was entrusted to tractor operators - machinists and craftsmen - adjusters. It was supposed that a part of complicated works on maintenance would be performed by more qualified master - adjuster [8]. To ensure trouble-free operation of tractors, a powerful industrial base for maintenance and repair of tractors was created. So, for example, for tractors of K-700 type there was a created materially-technical base, making capital expenses of 0.45 - 0.52 rubles per ruble of balance value of a tractor [9]. But also it has not been essentially effective in the decision of a problem of increasing the non-failure state of technics. The enterprises of agricultural machine building practically did not show special interest in increasing the reliability of machines.

At the time of Machine-Tractor stations, the mechanic’s workload with machinery maintenance work was much lower and in this case the effect of specialization and concentration of work is evident. Now mechanizers almost half (about 56%) of working time are engaged in maintenance and repair of machines, the volume of maintenance and repair work, which accounts for one mechanizer, has increased from 15% to 85% [10].
According to engineering and technical personnel, the load of a mechanizer with maintenance and repair work should not exceed 20 - 25%. If the maintenance is carried out by the tractor driver himself, he performs only 24% of the total number of planned services. If a master mechanic is connected and he combines the duties of a locksmith to troubleshoot, the amount of work is performed by 43% with a full specialization of 89% [11].

4. Purpose of the Study
The purpose of the research is to find optimal solutions to increase reliability and productivity of tractors by reducing the tractor driver's workload with maintenance and repair work through specialization and intensification of technical service. This allows one to reduce downtime in busy periods of field work, as well as transfer part of these works to the implemented dealer system of technical service, depending on the profitability of agricultural enterprises.

5. Research Methods
The main research methods used were observation methods directly under operating conditions, data from literature sources with assessment of comparability of conditions, as well as data from experiments conducted on farms.

6. Findings
From the above, we can conclude that it would be expedient to transfer part of the scope of maintenance and repair work to specialized enterprises, as because of high specialization and technical equipment, the quality of such work will be higher than that in the farm. All this creates prerequisites for the formation of the dealer system of branded service [12].

According to the Ministry of Agriculture and Food of the Omsk region, the structure of the agricultural machinery park in 2016-2019 looks as follows (figure 2).

![Figure 2. Structure of the agricultural machinery park in 2016-2019](image)

The analysis of the data shows a tendency to reduction of the machinery fleet in almost all groups, the machinery and tractor fleet is being renewed at a very weak rate (figure 3). For certain machine groups (e.g. tractors), the renewal rate is very low, stable all over years and within the statistical error limits.

Thus, it can be concluded that the machine and tractor fleet is annually aging and shrinking in order to perform all kinds of work at the enterprises of the agro-industrial complex. It is necessary to use the existing equipment more efficiently by organizing the system of maintenance and repair of machines operating in modern conditions. Figure 4 shows the availability of the main types of agricultural
machinery at the enterprises of agroindustrial complex of the Omsk region with the term of operation over 10 years, %.

**Figure 3.** Percentage of renovation of main types of machinery and equipment for 2016-2019, %

**Figure 4.** Availability of main types of agricultural machinery with an operating life of over 10 years, %

As can be seen from the graph, more than 50% of tractors and sowing machines are outside the recommended operating times. For the group of tractors we have prepared a polygon for the age distribution of the existing fleet. Figure 5 shows the age distribution range of tractors in farms of Omsk region.

As can be seen, the average age of tractors is 26 years, including tractors of 5-ton class (K-700 type) - 27 years, and foreign cars - 8 years. It is clear that the dealer service can not take for service the equipment, which is already in operation due to the lack of the material-technical and financial base, as well as the actual absence of the consumer of services. Formation of the dealer system of technical service of agricultural machinery is believed to be possible from the moment of its sale under warranty service.

For example, the technical center of Sibirskaya supply base, one of the largest in the Omsk region, makes not only warranty repair of equipment, but also post-warranty service, as well as current repair of equipment purchased not only at the base, but also in other organizations. The technical center of the Sibirskaya supply base employs 14 people to carry out maintenance and repair of equipment. They were given a maintenance unit equipped with equipment for technical service-1 and technical service-2 and to eliminate the consequences of failures.

The analysis of warranty service requests for 2019 showed the unevenness of labor intensity of maintenance and repairs by months. Thus, for example, for February month of 2019, 9 requests with total labor intensity of 94.2 man-hours were satisfied, including the elimination of the consequences of failures 64.2 man-hours. Labor intensity of warranty service for the first half of 2019 changed during the year (figure 6).
When drawing up the mathematical model of formation of technical service at maintenance of the machines which are under guarantee, in our opinion, the following should be considered. The consumer of services in the sphere of technical service of agricultural machinery can be formed at a certain value of profitability of an agricultural enterprise in the form of profit (E). From this profit, the enterprise can spend on technical service, including third parties, additional costs $\Delta E_{\text{cost}}$ and get additional profit $\Delta E_{\text{ad}}$ as a result of reduced repair work due to quality technical service and reduced time of field work. It can be assumed that funds allocated for maintenance and repair of equipment (MR) to third parties will amount to $\Delta E_{\text{cost}} \leq \Delta E_{\text{ad}}$. The cost formation model [10] can be significantly simplified, if specific time for maintenance is introduced into the functionality with the total tractor downtime due to technical reasons (figure 5).

$$
\sum_{j} t_{ji} f(A_2) - \sum_{j} t_{ji} f(A_1) \cdot C_{\text{hour}} \cdot m_{j} \leq E_{\text{ad}}.
$$

(1)

However, in determining the number of service channels and the number of performers, we inevitably face the following kind of difficulties. As it was shown in [13], the number of requests for maintenance and repair is determined by the complex process of restoration, which is formed depending on the quality of maintenance and aging of equipment. With a variety of branded composition of the serviced equipment, it is impossible to solve this problem correctly in practice. Therefore, if we consider the formation of maintenance requests by periods of equipment use at constant tif(A2) and tif(A1) (the effect of the effect is excluded), it seems possible to use a simpler mathematical apparatus of mass maintenance theory. Then the average time of waiting (twait) service, elimination of failures, repair of equipment at warranty and post-warranty service is equal to $\mu$:

**Figure 5. Age of tractors in farms of Omsk region**

**Figure 6. Labour intensity of the application for maintenance and repair in the first half of 2019**
\[ t_{\text{wait}} = \frac{\lambda}{\mu(\mu - \lambda)}, \text{ where } S=1, \quad (2) \]

where \( S \) – service channel number; \( \mu \) - service intensity, \( \mu-1 \) and \( \lambda \) - service intensity.

\[ \mu = \frac{1}{t + t_{\text{mov}}}, \text{ mobile service.} \]

\[ t_{\text{mov}} - \text{average moving time of a mobile unit when a single service request is fulfilled.} \]

According to observations, the possible daily mileage (L km) of the unit by car is:

\[ L_{\text{att}} = 15.1M_{\text{gv}} + 2.3R + 3.37r - 14.5 \text{, km} \quad (3) \]

where \( M_{\text{gv}} \) – number of applications per day in the v period; \( R \) – distance from the service base (concentration of technical service facilities) to the central farmstead, km; \( r \) – average radius of the production unit, km.

If the tractors are focused on the central estate \( r =0 \). The number of staff \( (M) \) is based on working time \( F_W \).

The working time fund for carrying out technical service and eliminating minor related failures by means of a mobile means is equal to:

\[ F_W = \left[ W_n \cdot W_h - \left( \frac{L_{\text{att}}}{V_u} \right) \cdot T_p \right] \cdot \tau, \quad (4) \]

where \( W_n \) – number of workdays, \( W_h \) – hours worked, \( \alpha \tau \) – time dilution factor.

Thus, if 94.2 hours of work are required, 1 master can be loaded incompletely, and in June 4 wizards are required (figure 6). This affects both their professional qualification (skills and abilities) and the enterprise economy. Under conditions of market relations, it is necessary to constantly improve the activity of the servicing enterprise.

In conditions of modern production of works at the enterprises of agroindustrial complex, it is necessary to relieve the excessive load on maintenance and repair of tractors, combines and agricultural machines from the mechanizer (figure 7). More than half (about 56%) of the total time of work the mechanizer is involved in the maintenance and repair of machines, elimination and waiting for the elimination of the consequences of failures. This leads to the fact that the scope of work on maintenance, elimination and waiting for the elimination of the consequences of failures and repair of machinery, even in the winter non-stressed period is performed poorly and not in full. On the main work the mechanizer spends about 42% of working time.

**Figure 7.** Diagram of the driver's employment during the year
That is why it would be expedient to specialize and concentrate maintenance works with their removal during a busy period, taking into account the requirements of GOST 207-2009 “Agricultural tractors and machinery. Technical service”, as well as transfer to specialized enterprises part of the volume of maintenance and repair work in a long stress-free period, with the confidence of their high specialization and technical equipment, more qualitative performance of work [14].

The mechanizer will spend about 73% of working time for the main work (figure 8), and the time spent on technical service, repair of machines, elimination and waiting for the elimination of the consequences of failures will be reduced to 25%. This will increase the productivity of machine and tractor units and the quality of work [15].

![Diagram of the driver's employment during the year of implementation of the new technical service system](image)

**Figure 8.** Diagram of the driver's employment during the year of implementation of the new technical service system

### 7. Conclusion

The following conclusions can be drawn from the carried out research.

1. One of the main contradictions in the system of maintenance and use of machines is the coincidence in terms of timing of mechanized and maintenance works.
2. The completeness and quality of maintenance, as well as the productivity of the machines, depends primarily on the load of the tractor driver and the concentration and specialization of the performed maintenance operations.
3. It is necessary to reduce the tractor driver's workload with technical service and repair works. For this purpose it is most expedient to transfer some of these works to specialized enterprises, where the quality of their performance will be higher than that in the farm. Transfer of works on complex types of technical service to the enterprise of specialized technical service at will allow one to release the mechanic from participation in performance of operations on technical service (TO-2, TO-3) and to increase reliability of tractors, and to reduce quantity of failures. The mechanic will spend about 73% of working time for the main work, which will increase the actual shift productivity of machine and tractor units by 14% and improve the quality of work performed.
4. At present, the prerequisites are being created for the formation of a dealer system of branded service, depending on the profitability of enterprises.

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