Ensuring the operational reliability of the tractor fleet

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Abstract. One of the major problems facing the engineering and technical service of agricultural enterprises is to figure out the volume of repair and maintenance impacts to ensure the optimal operation of the tractor fleet in conditions of limited financial resources. The study introduces individual reliability indicators of tractors, based on the analysis of the machine and tractor fleet in the Vologda region. The condition for the formation of rational and effective repair and maintenance impacts is the constant monitoring of reliability indicators of tractors and agricultural machinery, which allows not only identifying their individual characteristics, but also predicting changes in technical state. Studies have shown that different systems of tractors, in particular MTZ tractors, can differ by reliability actually n several times. The interrelation between the invested funds for repairs and the subsequent failure-free operation was found out. The increase of failure-free operation allows reducing the probability and the amount of downtimes in the busy farming season, thereby reducing the possible costs associated with losses due to downtime of machines, such as: violation of agro-technical terms, which is especially important for sowing and harvesting, being one of the factors of yield reduction. These studies laid the foundation for the method for determining the rational volume of repair and maintenance impacts, which consists in minimizing the total costs aimed at improving the failure-free operation of tractors. All this, along with using the up-to-date diagnostics tools, will increase the efficiency of preventive repair and maintenance impacts.

1. Introduction
In contemporary, rather difficult economic conditions, taking into account the policy of import substitution, including agricultural production, the effective maintenance of the tractor fleet is one of the most important tasks for enterprises of agro-industrial complex [1].

The purpose of the study is to improve the operability and reliability of tractors and agricultural machinery in the conditions of the European North. The methods of analysis and synthesis, mathematical and simulated, physical modeling, mathematical statistics and programming were used in the work.

In recent decades, a large number of scientific developments of Russian and foreign authors are devoted to the reliability of individual aggregates, assemblies and components of agricultural machinery. A significant contribution to the development of general theoretical and practical aspects of increasing reliability was made by Russian scientists; in particular V.A. Smelik considered the technological reliability as a complex and multifaceted object for a research [2].
The reliability of tractors and agricultural machinery is the subject of theoretical studies in foreign literature, in particular among such well-known authors as V.E. Deming [3], P. Moers [4, 5], J. Kettel [6], Z. Hellerman and many others [7–10].

In spite of the existence of many scientific works in the field of assessment and ensuring the reliability of tractors and agricultural technics, there is no unified approach to determining the rational volume of repair and maintenance impacts, which can identify the reliability level of technics and increase the efficiency of repair and maintenance impacts on the basis of using the modern diagnostics tools.

For the engineering and technical service of an agricultural enterprise, an uneasy task is set annually: to provide the reliability level of technics with minimum costs during the busy periods of tractor fleet use, such as sowing, harvesting of juicy and coarse feed, harvesting grain, etc.

2. Experimental

The main tractors in the agricultural enterprises of the Vologda region now are the tractors with engine power of 39.72 – 73.55 kW (54–100 hp), the basis of which are the MTZ-82 tractors and their modifications (figure 2).

![Figure 1](image.png)

**Figure 1.** Power characteristic of the tractor fleet in the Vologda region.

The number of 1,4 drawbar category tractors is on the average of 10 to 15 units in the structure of the tractor fleet of an agricultural enterprise.

The studies conducted on the farms of the Vologda region showed that the reliability of tractors was individual and could differ, even in the conditions of the same farm [1].

With an average age of the tractor fleet of about 6 years, the average run-to-failure is only 185.6 machine hours, which is 71% of the norm. The values of run-to-failure in the machine hours in the tractor fleet under the study may differ by 1.67 times. It should be specified, that a reliable correlation between tractor age and its reliability indicators is absent, and the correlation coefficient between tractor age and run-to-failure is - 0.27 (Table 1).

| Registration number of a tractor | Age, years | Run-to-failure(machine hours) | Run-to-failure in % to normative (machine hours) |
|---------------------------------|-----------|------------------------------|-----------------------------------------------|
| 98                              | 11        | 178                          | 69                                            |
| 110                             | 9         | 193                          | 75                                            |
| 123                             | 8         | 147                          | 57                                            |
| 135                             | 7         | 146                          | 57                                            |
3. Results and considerations

The studies prove that the reliability of a particular tractor is individual, the formation of a difference in reliability indicators begins during assembly on the conveyor belt, various conditions of tractor maintenance and the human factor contribute to the individualization of indicators.

The study of the dependencies between the investment of funds for the elimination of failures and the subsequent time between failures allowed coming to conclusion that to ensure the same level of reliability (time between failures) for different tractors, a different amount of funds was required (figure 2).

Considering the fact that the prices for spare parts and the cost of maintenance and repair are subject to constant changes, it was decided to bring the cost of increasing reliability and the cost of downtime in shares of the tractor cost.

\[
C = k_1 \times T_o^2 - k_2 \times T_o + c
\]

where, \( C \) – the cost to provide the required run-to-failure; \( T_o \) – run-to-failure, which must be ensured by carrying out preventive repairs; \( k_1, k_2, c \) – the individual coefficients for a particular tractor, specifying the nature of the curves.

[Figure 2. Dependence of the invested funds on the time between failures:a) tractor No. 141; b) tractor No. 142.]

Monitoring of reliability indicators in the process of the tractor operational activity will allow quickly adjusting individual coefficients (the values of which can differ in research results several
times), but also the function itself, equation 1, thereby increasing the efficiency of repair and maintenance impacts.

Machines downtime due to elimination of failures can lead to losses, yield reduction due to violation of agro-technical terms, reduction in milk yield of cattle due to disruption of feeding regimes, losses during harvesting, etc. Investment in repair and maintenance impacts is aimed at ensuring of reliability (reducing the cost of eliminating failures) during busy periods and reducing the possible damage from downtime due to failures.

The question arises about the most effective investment of funds in repair and maintenance impacts to ensure rational reliability indicators. This problem can be solved by determining the extremum of the total costs curve, which is the sum of the costs for repair and maintenance impacts (the costs for increasing reliability) and the costs for eliminating the resulting failures (figure 3).

4. Conclusion
This method (figure 3) will not only determine the minimum amount of money to ensure the reliability of the tractor fleet, but also provide rational run-to-failure, which will be 191 conventional reference per hectare with tractors loading in a busy period of 550 conventional reference per hectare.

In the conditions when the renewal of the tractor fleet occurs at low rates [1], the problem of ensuring the reliability of technics should be based on the constant monitoring not only the tractor fleet technical state, but also the agricultural machines fleet as a whole [2]. In addition, constant adjustment of individual reliability indicators is necessary.

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