Resource-Saving Approach to Planning of Repair-Maintaining Influences

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Abstract— **Under current conditions of development of the agri-industrial complex, one of the most important factors providing the readiness of the technics for performance of agricultural works is the financial resources directed at purchase of expendable materials and carrying out scheduled operations of preparing the technics for troubled periods of exploitation during sowing and harvesting seasons. The study of individual indexes of reliability through the example of the tractors MT3 introduced in the article, and dependences between investments in carrying out preventive-preparative operations and further run-to-failure time of the tractors will allow minimizing, firstly, financial and, secondly human and energetic resources, proving the necessary level of reliability of technics used for the most important agricultural operations that finally will be one of the factors defining the finished prime-cost of agricultural production.**

Keywords— *reliability; tractor fleet; run-to-failure; repair-maintaining influences.*

I. INTRODUCTION

Nowadays, there are 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 the agro-industrial complex. [1].

The problem of determining the volume of repair and servicing actions to ensure the effective operation of the tractor fleet in conditions of crisis in the economy is one of the most acute problems facing agricultural enterprises. The basis for the formation of rational and effective repair and servicing actions is the continuous monitoring of the reliability indicators of tractors and other equipment, allowing one not only to identify their individual characteristics, but also to predict changes in the technical condition.

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 have been 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 the 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], G.V. Redreev [4], J. Kettel [8], and many others [5, 6, 7, 9, 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 actions, 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.

Provision of the required level of readiness of the tractor fleet is ensured by timely and high-quality repair and servicing affects. The most common strategies of repair and servicing actions are of three types: the use of repair and servicing actions on demand after a failure, the performance of routine work depending on the operating time or service life and on the state determined by the results of periodic diagnostics, control.

In the case of M&S of a complex product, several strategies are generally applied, each – according to the specific component. For example, elimination of a sudden failure, for example, rip of the fan belt of the engine cooling system occurs according to the first strategy; replacement of engine oil – according to the second one; replacement of the cylinder-piston group of the engine – according to the third.

In the course of development of the methods and means of technical diagnostics, the scope of application of the third strategy is expanding.

Depending on the adopted strategy, technical requirements for repair and servicing actions change. For example, in the first strategy, the permissible deviation of the control parameter is equal to the maximum deviation; in the second one, it is zero. In the third strategy, it has an intermediate value between zero and maximum deviation.

Each strategy has its own tactical peculiarities. Thus, for tractors and agricultural equipment, a routine-preventive strategy of repair and servicing actions by the condition. Scheduled operations include regulated periodic vehicle maintenance, scheduled monitoring (diagnosing) of the vehicle's condition and docking it after exhaustion of the assigned residual life.

Preventive works include works aimed at preventing failures and malfunctions of vehicles. The components are regulated, restored, replaced so that the parameters of their technical condition do not exceed the limit value during operation, and the aggregates do not reach the limiting state. That is why the system of permissible parameter values is used in reference documentation. For this purpose, the residual life of the components and the vehicle as a whole is predicted. However, in each case, the strategy of repair and maintenance actions is optimized, a common solution is developed.

An optimal strategy is chosen by means of the objective function - a formalized record of the selected goal, taking into account a number of restrictions. If a target function and a system of restrictions are formulated, then the task of optimizing the strategy of repair and servicing actions is set. The next step is to find its solution.

Optimization of a strategy implies a choice of three possible best strategies. The optimal strategy should be feasible and provide the achievement of the goal - the necessary extremum of a specified criterion.

Optimization of the strategy of repair and servicing actions allows solving a number of specific problems of control during both maintenance and repair.

During maintenance, first of all, the frequency is established based on optimization of the operating time between the types of maintenance and the nomenclature of operations for each type. At the same time, optimal permissible values of the parameters of the technical condition of the vehicles are used.

The selected strategy allows determining the resource parameters of the components, according to which the residual resource should be predicted, and the rules of setting the type, volume and time of repair of the vehicle by the results of diagnosis should be applied

The correct choice of the strategy of repair and servicing actions makes it possible to reasonably choose ways to improve the quality of repair, to find the optimal degree of restoration of the component during repair, or average time to failure during maintenance. In addition, it is possible to solve specific repair tasks, for example, reducing the shortage of spare parts by changing the permissible wear of the parts of the interfaces during fault detection, pre-repair diagnostics of the vehicle, etc.

In each strategy of repair and maintenance actions, to preserve and restore the working efficiency of components, certain indicators that control the condition and reliability of the machine are used.

As an evaluation criterion of choosing the strategy of repair and servicing actions, it is most expedient to accept costs per unit for various strategies. Therefore, for example, the first strategy will be preferable when the expenses caused by the

failure are almost equal to the costs associated with the preventive restoration of the component. The second strategy will be optimal in cases when the expenses for diagnostics are very high or there are no diagnostic tools.

Along with the choice of the strategy and quality of repair, the running efficiency of the vehicle, compliance with operational requirements, and the timeliness of performing repair and servicing actions are of great practical importance. One of the crucial values in the operation of tractors in agriculture is the attitude of the machine operator.

This parameter has a pronounced individuality since there are no two machine operators, maintaining equipment with equally high quality.

Since the quality of an object is its individual characteristic, one can note that objects produced from the conveyor have both different quality and different reliability. Having even insignificant differences in reliability at the beginning of operation, in further operation, due to the significant difference in operating conditions, these differences will be even greater.

Consideration of reliability of machinery as a guarantee of performing the scope of work within a prescribed period and as a property of the quality of an object determines the following principles of the approach to reliability as the most urgent problem of operating the equipment in modern conditions of development of the agro-industrial complex. In the current economic situation, the problem of providing the necessary, required level of reliability comes to the fore. Provision of the required level of reliability, as a property of an object quality, must be of individual nature allowing one, depending on the technical condition of a particular tractor, to ensure its reliability and guarantee the performance of the set task. Due to inability to use reservation, reliability of the tractor fleet must be considered in aggregate, providing reliability of a particular tractor, thereby guaranteeing the fulfillment of a given amount of work by the entire fleet of tractors while minimizing the expenditures for repair and servicing actions.

To search for an optimal strategy of repair and servicing actions, at the initial stage of the research, the reliability indicators of the most widespread makes of tractors were assessed, significant differences were revealed, emphasizing necessity of an individual approach when performing repair and servicing actions.

II. EXPERIMENTAL

At the moment, the main tractors in the agricultural enterprises of the Vologda region 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.
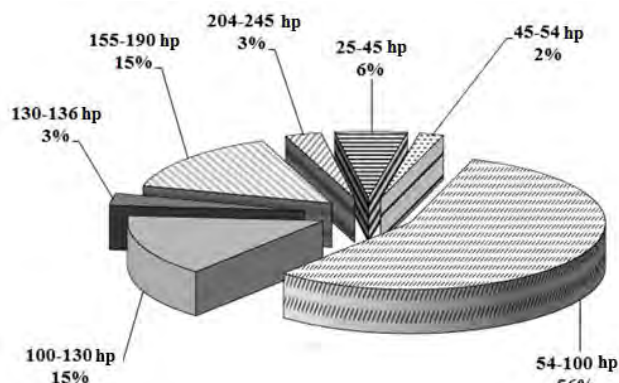
Fig. 1. Power characteristic of the tractor fleet in the Vologda region

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

TABLE I. GENERAL CHARACTERISTICS OF MTZ-82 TRACTORS FLEET

Registration number of a tractor	Age, years	Run-to-failure (machine hours)	Run-to-failurein % to normative (machine hours)
98	11	178	69
110	9	193	75
123	8	147	57
135	7	146	57
136	7	177	69
138	7	188	73
141	6	131	51
142	6	208	81
145	5	201	78
146	1	162	63
151	4	198	77
152	4	244	95
153	4	240	93

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 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).

III. RESULTS AND DISCUSSION

Analyzing the power characteristics of the tractor fleet (Figure 2), one should note an increase in the engine power of the purchased equipment. Thus, for more than 30 years in the period from 1980, the growth of tractor power was 76 l/s per unit on average throughout the park, which was 73% in relative terms.
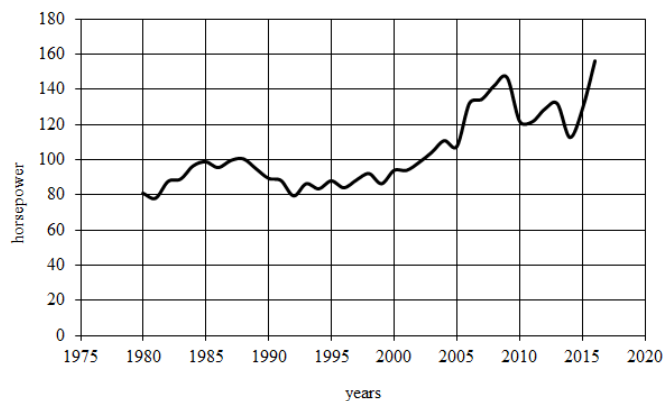

Fig. 2. Dynamics of changing power charcateristics of tractors

An increase in the power of operating equipment puts in the foreground the problem of increasing the efficiency of its use in order to ensure the required level of reliability of technological processes (technological reliability) in agricultural production sectors, thereby having provided the country's food security and competitiveness of domestic producers of agricultural products in the world markets.

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 concluding that to ensure the same level of reliability (time between failures) for different tractors, a different amount of funds was required (Figure 3).

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.

The increase in no-failure operating time allows reducing the likelihood and a number of downtimes during the most busy periods of agricultural works, thereby reducing the possible expenditures associated with losses due to equipment downtime, such as: violation of agrotechnical periods, which is especially important during sowing and harvesting works, being one of the factors of reducing crop yield.
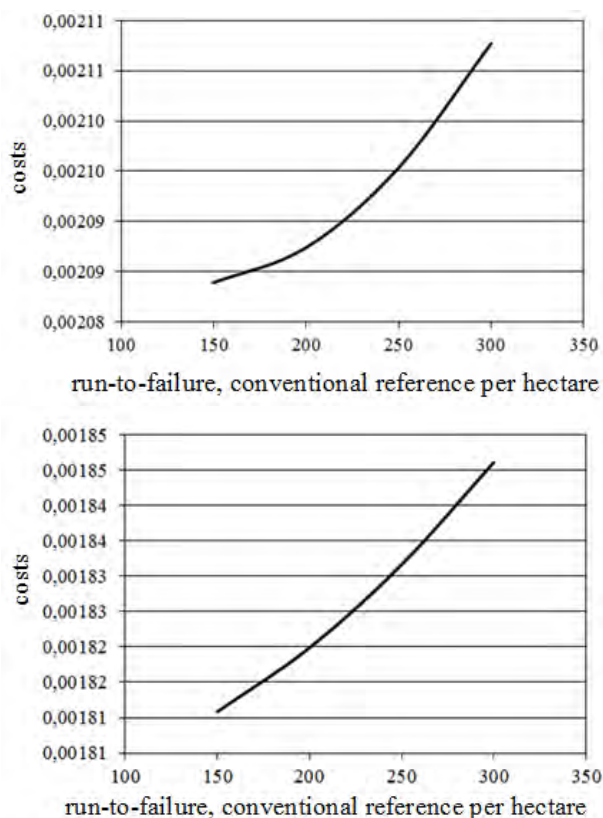
Fig. 3. Dependence of the invested funds on the time between failures of: a) tractor No. 141; b) - tractor No. 142

The function of the dependence of the cost providing the required run-to-failure in the general form is represented by the formula:

$$C = \text{k}_1 \times T_o^2 - k_2 \times T_o + c \qquad (1)$$

where C - the cost to provide the required run-to-failure; T_0 - 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.

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

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 actions is aimed at ensuring the reliability (reducing the cost of eliminating failures) during busy periods and reducing the possible damage from downtime due to failures.

The problem of the most effective investment of funds in repair and maintenance actions to ensure rational reliability indicators arises. 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 actions (the costs for increasing reliability) and the costs for eliminating the resulting failures (Figure 4).
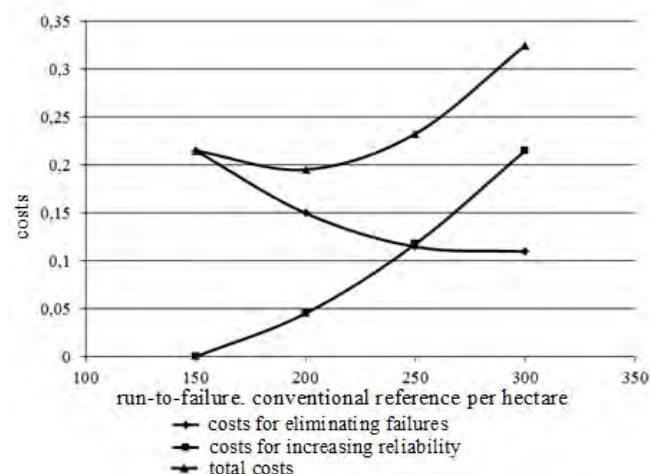

Fig. 4. Costs for increasing reliability and eliminating failures

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 references 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 vehicles should be based on the constant monitoring of not only the technical state of the tractor fleet, but also the agricultural vehicles' fleet as a whole [2, 18, 19]. In addition, constant adjustment of individual reliability indicators is necessary.

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