Research on the development of the agricultural sector of the Northern zone: repair and maintenance of machines

G E Kokieva¹, V P Druzyanova² and S I Grigoriev²

¹Arctic State Agrotechnological University, 3, Sergelyakhskoe highway, 3 km, Yakutsk, 677007, Russia
²Ammosov North-Eastern Federal University, 17, Krasilnikov Street, Yakutsk, 677021, Russia

E-mail: druzvar@mail.ru

Abstract. The use of complex and expensive equipment in agricultural production has significantly increased the requirements for the quality and timing of full performance of all the operations for its maintenance and storage. Nowadays the technical policy in the agro-industrial complex consists in the implementation of prompt and promising measures to satisfy agricultural producers and processors with high-quality, environmentally friendly and safe equipment, its efficient operation, a high level of mechanization and automation of labor, as well as the creation of a market for technical means and services. At the same time, a complex of measures that would consider both tactical and strategic situations in the context of the economic crisis is very important. In all cases, its starting point should be machine technology for the production of agricultural products and their processing, taking into account the peculiarities of the natural and climatic zones of the country. This is explained by many reasons, one of which is a decrease in the technical potential of village: the composition of machine and tractor fleet is decreasing and the physical and intellectual wear of equipment is progressing. According to the standard technology, the standards were created for labor costs for the repair of machines, standards for the consumption of materials required for repairs and rates for the use of spare parts. The practice of mass introduction of standard technology and norms has confirmed their high efficiency. The economic feasibility of restoring parts is usually assessed by the comparison of the cost of a new part and the cost of repairing a worn one. However, this does not take into account the difference in the service life of new and reworked parts and the additional costs associated with this.

1. Introduction

The problem of improving the reliability of equipment operated in extreme conditions of the Far North has now developed as an independent scientific direction based on the provisions of modern reliability theory, probability, mathematical statistics, destruction mechanics, and technologies for creating and restoring machine parts, as well as methods of planning and restoring operability [5].

Economic calculations related to the determination of the efficiency of agricultural machinery should take into account not only the costs of purchase and operation, but also the losses that a farming unit will incur due to the downtime of a particular machine or equipment. The total service life of a modern agricultural tractor before it is removed from service is on average 8-10 years. At the same time, the duration of uninterrupted operation of a new factory-made tractor from the first repair is approximately 3000 operating hours. The rest is provided due to its periodic repairs. In terms of its volume and technological content, repairs can be equal to the process of the creation of new machine, since as a
result, not only a tractor performance is fully restored, but also its durability and reliability are renewed within certain limits. Repair is an integral and inevitable continuation of the process of the creation of a tractor. The durability and reliability of a repaired tractor depend on the established overhaul period, as well as on the technical conditions for troubleshooting, completing and repairing parts. During the repair process, it is possible to set the optimal values of durability and reliability, ensuring the minimum cost of the subsequent operation of a tractor. The consistent development of the material and technical base of the agro-industrial complex and agricultural engineering make it possible to provide farms with high-performance equipment. Farm specialists purchasing new machines must have a deep knowledge of modern means of mechanization, including the economic aspects of operation. In repair facilities, which organize the production process in accordance with this technical documentation, the time spent on repairs has significantly reduced, labor productivity has increased, the number of workers employed in repairs has reduced and wages have stabilized, the quality of repairs and the general principle of repair facilities have improved. The modern main indicators for the assessment of the economic efficiency of servicing machines are the monetary costs of maintenance, referred to the unit of production of machines and the utilization factor of service facilities. These criteria can be used in full and timely provision of machines with appropriate types of services. The actual trends of agricultural and rural development of the North contradict the principles of sustainable development [2].

2. Research methods
The quality of the repair of machines and their engines is assessed using both objective and subjective methods. The purpose of the research is to obtain as much useful information as possible about the reliability and durability of all machines, based on the results of the study of a number of randomly selected objects, on the basis of which it would be possible to draw conclusions about the average periods of normal service life of equipment and the probability of its failure at that or another moment in time. Both of these tasks can be solved if the distribution of the duration of the effective functioning of the machine is known. In fact, this is not true, especially for modern machines with replaceable structural elements. The running-in of replaceable structural elements of equipment as an operation of the technological process of one or another type of maintenance or repair is performed in extremely insignificant volumes and does not refer to many structural elements at all [1-5].

| №  | Characteristics                                         |
|----|--------------------------------------------------------|
| 1  | Downtime rate of machines for service and waiting       |
| 2  | Service maintenance factor                              |
| 3  | Probability that a machine requiring maintenance will be serviced no later than after a specified period of time |
| 4  | Probability of available running machines out of the total number |

Table 1. Service evaluation characteristics

The analysis of the recommended criteria for the support of the permissible values and the frequency of inspection of the engine parameters showed that the most accurately posed problem is solved on the basis of a technical and economic criterion. The objective function that implements the stochastic version of the technical and economic criterion has the following form:

\[
G(D, t_M) = \Pi_n < D < \Pi_n \leq t_m \left\{ \frac{\left[ AQ(D, t_M) + C[1 - Q(D, t_M)] + BK_\Pi(D, t_M) + S(D, t_M) \right]}{T_q(D, t_M)} \right\},
\]

where \( G(D, t_M) \) – unit operating costs depending on the permissible value of the parameter D, frequency of inspection \( t_M \); \( A, C, B \) – costs of the elimination of the consequences of failure, planned restoration, diagnostics; \( K_\Pi \) – average number of inspections over the life of an element; \( S \) – continuous costs reasoned by the changes in the technical and economic indicators of the diesel engine as the parameter
changes; \( Q \) – probability of failure during the life of an element; \( T_\phi \) – actually used resource of the element; \( \Pi_H, \Pi_n \) – nominal, limit value of the parameter.

For the parameters of the running system, gearbox and some other machine units, this assumption can be considered fair, since the limiting clearances result in increased knocking, increased vibration, breakdown of parts, i.e. they have a pronounced symptom of failure. The parameters of an engine, as a rule, do not have such a clear relationship between the limit value and the specific symptom that characterizes its achievement [2-8].

3. Results and discussion

The expression (1), however, does not imply the presence in operation of elements with superlimiting values of parameters. Such a discrepancy between theoretical premises and practice requires the need to take into account the degree of discrepancy between the moment of failure and the moment of elimination of its consequences when justifying the allowable values and the frequency of examination of engine parameters. As a quantitative characteristic of this phenomenon, it is proposed to introduce the indicator “probability of failure detection”, which is the ratio of the number of detected failures to the total number of elements that failed in the intercontrol period:

\[ Q_{o6} = n_B/(n_B + m), \]  \( \text{(2)} \)

where \( n_B \) – the average number of restorations of the initial value of the parameter in the intercontrol period; \( m \) – the average number of parameters exceeding the limit value by more than 10%.

The probability of the simultaneous occurrence of two random events (the first one when the failure has occurred, the second one when it is detected) determines the probability of eliminating the consequences of the failure:

\[ Q_y = Q \cdot Q_{cm} + K_{Q,Q_{cm}}. \]  \( \text{(3)} \)

Where \( K_{Q,Q_{cm}} \) – correlation moment

It is obvious that the actually used resource \( T_\phi \) of the expression (1) also does not coincide with the operating time until the moment of real restoration, since they differ by the operating time value of the element operated with the transcendental value of the parameter. The calculation of continuous costs also has a significant difference. If in the expression (1) they were determined by the formula:

\[ S = a U_A, \]  \( \text{(4)} \)

where \( a \) is a coefficient connecting the increase of continuous costs (losses from a drop in engine power, excessive consumption of fuel, oil, etc.) when the parameter changes from the nominal to the limiting value; \( U_A \) is the integral change in the set of similar parameters to the limiting value. Thus, provided that the value of the parameter in operation can exceed the limiting value, the formula for the determination of continuous costs will take the following form:

\[ S = c U_B + (a - c) U_A^{T_\phi/T_B}. \]  \( \text{(5)} \)

where \( c \) is a coefficient connecting the increase of continuous costs when the parameter changes beyond the limit value; \( U_B \) is an integral change of the set of similar parameters to the value corresponding to the real restoration.

Thus, it is more correct to justify the permissible values and the frequency of examination of the engine parameters on the basis of the following objective function:

\[ G(D, t_M) = \min\{A Q_y(D, t_M) + C [1 - Q_y(D, t_M)] + \Pi_H < D < \Pi_n 0 \leq t_M + BK_{11}(D, t_M) + S(D, t_H, Q_{o6})/(T_B(D, t_M, Q_{o6})) \} \]  \( \text{(6)} \)

where \( T_B \) – operating time until the initial value of the parameter is restored.

The best way to obtain such information is long-term field tests of a sufficiently large part of identical objects for a time exceeding the wear resistance of the main machine parts. With failure, machines reveal their weak points, thereby determining the limiting values of failure indicators [5-8].
The characteristic of the reliability of a machine is determined by the following formula:

\[
\lambda_M(t) = \sum_{i=1}^{s} \lambda_i(t) + \sum_{j=1}^{z} \xi_j(t),
\]

where \(\lambda_i(t)\) and \(\xi_j(t)\) – the risk of failure, respectively, of structural and non-structural elements.

However, non-structural element (such as lubrication, painting, etc.) affects the working and operating conditions of structural elements and, therefore, \(\lambda_i(t)\) is a function of \(\xi_j(t)\).

Thus, the introduction of the parameters \(\lambda_i(t)\) and \(\xi_j(t)\) is not justified, since it is impossible to obtain numerical values separately for \(\lambda_i(t)\) and \(\xi_j(t)\) and give a calculation or assessment of the reliability of the machine based on them [9, 10].

A suggested formula to summarize the risk of failure is as follows:

\[
\sum_{t=0}^{t=T} \lambda_M(t) \cdot \Delta t = \sum_{t=0}^{t=T} \left[ \sum_{i=1}^{s} \lambda_i(t) + \sum_{j=1}^{z} \xi_j(t) \right] \Delta t
\]

In this form, it even loses the meaning for \(\lambda(t)\), previously adopted by the formula (1), since in each particular case, when calculating \(\lambda_M(t)\), \(\lambda_i(t)\) and \(\xi_j(t)\), they should be multiplied by the time interval \(\Delta t\).

At the same time:

\[
\lambda_i(t) \cdot \Delta t = \frac{n(t)}{H(t)} \cdot \Delta t = \frac{n(t)}{H(t)}
\]

The final result of various studies on machine wear is to determine the patterns of wear increase and establish their service life. In the scientific and educational literature, the final data on wear is usually drawn up in a graph that can be called classic (Fig. 1).

![Figure 1](image-url)

**Figure 1.** Generally accepted construction of the wear line of various objects

The wear and tear of each machine is a continuous process. Its components are the wear of all elements of equipment under the influence of loads arising during its operation, transportation and storage [6-8]. Each of these types of machine loading increases quantitatively as the equipment ages and none of its components ever decreases and it follows that as the machine ages, its general wear and tear continues to grow. The fact that in many cases the intensity of work, for example, of a tractor, sometimes increases (spring, winter plowing), then decreases (winter), does not change the situation, since the stop of wear cannot reduce the wear that has already taken place. In addition, during the period when the machine is not working, the wear and tear that occurs during storage continues to grow.
4. Conclusion
In the system of operational measures associated with the increase of the durability of engines, an important place is occupied by the control of the main indicators of the operation and technical condition of an engine in the field. Reliability is quantitatively determined by the probability to complete a task on time with an appropriate quality of work. Then the failure rate is determined, which shows what fraction of the total number of parts fails over the considered period of time. Thus, it can be noted that reliability is an important indicator, but not sufficient for a complete characterization. The machine must be assessed for maintain ability and durability.

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