Rational maintenance of the use of technics

G Kokieva 1,2,3, A Koryakin 2, I Ammosov 2, S Klimov 2, and Sh Yusupov 2

1 North-Eastern Federal University named after M.K. Ammosov, Belinsky st., 58, 677007, Yakutsk, Republic of Sakha (Yakutia), Russia
2 Arctic State Agrotechnological University, Sergelyakhskoe shosse, 3 km, building 3, 677007, Yakutsk, Republic of Sakha (Yakutia), Russia

E-mail: kokievagalia@mail.ru

Abstract. The priority area of engineering activities to ensure the operability of machines and reduce the intensity of their wear is currently maintenance. Modern and high-quality performance of this work allows you to reduce by 30 ... 35% just during repair, for technical reasons, by 25 ... 30% to reduce the consumption of spare parts, by 18-20% of fuel and lubricants during the operation of the machine and tractor fleet. However, observations show that the impact of maintenance on the productivity of the machine and tractor fleet has noticeably decreased in recent years. Practically the only way to determine reliability, durability and wear resistance is testing. Even those few researchers who develop analytical methods for calculating these characteristics are forced to rely on empirically obtained data. The existing methods of operational testing do not provide objective information about the reliability, durability and wear resistance of machines. The article provides a research methodology that is carried out according to the quantitative characteristics of the reliability of elements. Reliability is quantitatively determined by the likelihood of completing the task on time with the appropriate quality of work. Then we determine the failure rate, which shows what fraction of the total number of parts fails during 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 evaluated for maintainability and durability.

1. Introduction
The cost and volume of agricultural production is largely due to the reliability of the equipment used. With a well-equipped repair and service base, the use of the latest diagnostic equipment, the organization of technological adjustment of machines, and quick troubleshooting, new equipment can provide high productivity inherent in its design and become profitable for the economy. The constantly growing shortage of spare parts for equipment of processing enterprises of the agro-industrial complex necessitated the restoration of worn-out parts. Now these enterprises are creating specialized sections with the required repair and technological equipment. Usually, when considering the wear characteristics of individual structural elements of equipment, it is considered that the first stage (running-in) and the last stage (forced wear) are outside the overhaul period and that during the entire overhaul period, the structural element is worn out under favorable operating conditions with a minimum wear angle. The problem of diagnosing the technical condition of machines is very urgent. Systematic monitoring of machinery mechanisms without disassembling them allows timely identification and elimination of malfunctions directly at the service point (during the next technical
maintenance), reducing the volume of installation operations, and preventing premature setting of machines for repair. [1-3]

2. Research methodology
The quality of repairs to machines and their engines is assessed using both objective and subjective methods. The purpose of the test is to obtain as much useful information as possible about the reliability and durability of all machines, based on the results of observations 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 operation of equipment and the likelihood of its failure at that or another moment in time [1-5]. Both of these problems can be solved if the distribution of the duration of the correct operation of the machine is known. In fact, this is not true, especially for modern machines with replaceable structural elements. 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 carried out in extremely small volumes and does not apply to many structural elements at all.

The best way to obtain such information is long-term field tests of a sufficiently large batch of identical objects for a time exceeding the wear resistance of the main machine parts [6-14]. When machines fail, they reveal their weak points, thereby determining the limiting values of rejection signs.

The reliability characteristic of the machine is determined by the formula:

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

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

But non-structural elements (lubrication, painting, etc.) affect the working and operating conditions of structural elements and, consequently, $\lambda_i(t)$ is a function from $\xi_j(t)$.

Thus, the introduction of 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, based on them, a calculation or assessment of the reliability of the machine.

The formula proposed to summarize the risk of failure:

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

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

Wherein:

$$\lambda_i(t) \cdot \Delta t = \frac{h(t)}{h(t) \cdot \Delta t} \Delta t = \frac{h(t)}{h(t)}.$$  

The end result of various studies on machine wear is to determine the patterns of wear growth and establish their service life.

3. Main part
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. Generally accepted construction of the wear line of various objects

The physical 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 [3,15]. Each of these types of machine loading increases quantitatively as the technology ages and none of its components ever decreases, which means 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, a tractor, sometimes increases (spring, winter plowing), then decreases (winter), does not change the position, since the suspension of wear, due to lack of work, cannot reduce the wear that has already taken place. In addition, during the period when the machine is not working, wear continues to grow during storage [2,9].

Now let's move on to determining the failure rate $\lambda(t)$.

Physically, $\lambda(t)$ shows what fraction of the total number of parts fails during the considered period of time. Let it be under supervision $N = 100$ parts (fig. 1), and up to the point in time $t_1$ they all work fine. For a period of time $t_1 - t_1 = \Delta t$ (for simplicity of calculation we take $\Delta t=1$) 10 parts have failed, then, applying formula (3), we get:

$$\lambda_1 = \frac{10}{100-90} = 0.1053$$

(4)

Let further, over the same period of time at the end of the test, the remaining ten parts fail, then:

$$\lambda_K = \frac{10}{100-1} = 2.$$  

(5)

The answer received from a physical point of view means that over the last period of time $\Delta t$ there were twice as many rejected parts as there were by the beginning of the interval $\Delta t$. It would be more logical if $\lambda_K$ will show that all available parts have been dropped. В этом случае:

$$\lambda_l(t) = \frac{h_l(t)}{H_{l-1}(t) \cdot \Delta t},$$

(6)

where $H_{l-1}(t)$ – the number of parts in good working order by the beginning of the considered period of time $\Delta t$.

For our example:

$$\lambda_k = \frac{10}{10-1} = 1.$$  

(7)

Thus, the intensity (danger) of failures $\lambda(t)$ is defined as the ratio of the number of parts that failed during the considered period of time to the product of the number of parts that worked properly by the beginning of the specified period by its duration [4,12].

The reliability of the facility at the operational stage can be illustrated by the graph of the typical dependence of the facility failure rate on the operating time, shown in Figure 2.
Figure 2 shows: 1 – failure rate λ (t); 2 – aging curve; \( t_p \) – running-in period; \( t_n \) – normal operation; \( t_i \) – the wear period.

Table 1 shows the recommended safety factors.

| №  | Name of failures | Formula                      |
|----|------------------|------------------------------|
| 1  | Emergency        | \( K_{em} = \frac{T}{T + T_{em}} \) |
| 2  | Wearable         | \( K_w = \frac{T}{T + T_w} \) |
| 3  | Technological    | \( K_t = \frac{T}{T + T_t} \) |
| 4  | Erroneous        | \( K_{er} = \frac{T}{T + T_{er}} \) |

Here \( T \) – time of clean machine operation during the test period. During the same test period, the time required to eliminate accidental breakdowns (accidents), \( T_{em} \), to replace worn parts \( T_w \), to adjust the machine to ensure the required quality of work \( T_t \), to eliminate malfunctions caused by errors of the operating personnel or the use of the machine for other purposes \( T_{er} \).

The full period of operation of the machine during the entire test period:

\[
T_f = T + T_{em} + T_w + T_t. \tag{8}
\]

Then the overall coefficient of technical reliability of the machine during the tests:

\[
K_T = \frac{T}{T + T_{em} + T_w + T_t}. \tag{9}
\]

If you are evaluating the reliability of mass-produced machines in the field to account for downtime due to organizational failure, but the analogy is the service reliability factor [6,8]:

\[
K_{or} = \frac{T}{T + T_{or}}. \tag{10}
\]

where \( T_{or} \) – time lost due to organizational problems.

Considering \( K_{or} \) machine reliability factor:

\[
K_{ex} = \frac{T}{T + T_{em} + T_w + T_t + T_{er} + T_{or}}. \tag{11}
\]

If all of the above factors are determined for a sufficiently large number of monitored machines, the value of each factor will be numerically equivalent to the probability of the correct operation of the fleet of machines [7,11].
Knowing the meaning of $K_T$ and the limits of its change, you can find the actual performance of the machine by the formula:

$$\Pi_T = K_T q \tau_T \text{ или } \Pi_{ex} = K_{ex} q \tau_T,$$

where $q$ – hourly productivity of the machine; $\tau_T$ – operating time of the machine, hour.

A structural element in a running machine wears out during the overhaul period with a transient wear mode, at least at the beginning and at the end of its service life. With each replacement of a structural element, the unsteady mode of its wear in the machine is repeated again and again. From this, there are corresponding changes in the intensity of wear and long-term structural elements, that is, in fact, all structural elements of the machine (and therefore the entire machine) wear out during their service life in an unsteady mode and are characterized by the presence of additional loads and additional freedom of movement in many interfaces with impacts etc. [6]

4. Conclusion

World experience in the operation of agricultural machinery shows that even the most perfect machine can realize its potential only under the condition of organized technical service. The complexity of the work performed in this case, their level of quality is largely determined by the economic interests of both machine manufacturers and their consumers and performers of the required maintenance services. In conclusion, we emphasize that reliability is a very important indicator, but not sufficient for the full maintainability and durability. The reliability of the machines to a large extent depends on the quality of their pre-operational run-in. The currently used methods of such running-in in the field are time-consuming and do not always provide the necessary preparation of equipment for production operation. In this regard, it is advisable to develop rational modes of accelerated running-in of new and repaired machines.

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