Increasing the efficiency of agricultural transport and technological machines in the operation

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Abstract. Production of commercial agricultural products is impossible without transport and technological machines and their technical-readiness, through repair and maintenance. The relevance of this direction is due to the agricultural producers' lack of necessary material and technical base, required production structures, taking into account multistructurality, and various forms of ownership. The use of transport and technological complexes and maintenance tool for their setting and adjustment allows to reduce labor costs and improve the quality of mechanized works. With the increase of commercial agricultural production technical capacity, some issues have emerged: increasing the costs of machines, increasing expenses of production per unit, and also the complicated operation system of mechanisms. As a result, the indicators of their use are not improved. Reformation of management methods in agriculture is aimed to solve the issues of technical and economic provision of agricultural products producers with the necessary technical resources. To solve this problem, differential standards of resource requirements should become essential, taking into account the production volume. It is necessary to increase the technical-readiness of transport and technological machines and thus the cost-effectiveness of their use.

1. Introduction

At present, the volume of works on the maintenance of agricultural machines are conducted by 60...80%, on diagnostics by 25%. The main reasons for this state - the farms' lack of necessary material and technical base, the poor organization of works performance, the engineers and technical workers' low level of training. The main reasons for this location are the lack of adequate material and technical base in the farms, imperfect organization of these works, and technical workers' weak level of training.

Issues of machines durability and reliability are interested not only scientists and machine engineers, but also consumers who operate machines, arrange their maintenance and repair. It can be explained by the fact that modern machines use structural members, assemblage, regulation, coloring, oiling, and other factors estimated at the different operating time, and requiring replacement or updating in contrast to the low-speed machines with a large strength margin. Unfortunately, many researchers involved in issues of reliability and durability overlook this important feature of modern technology, whereby it makes their recommendations ineffective. Moreover, the indicator of machine
durability, like any other compound object, should take into account operating time of elements included in its, but also their share in the total volume and their responsibility for the machine operating time. The latter circumstances show the comparison of two machines with the same operating time, one of them often requires replacement of only small and cheap parts, and the other one requires replacement of large and expensive parts. The characteristics of machine durability and operating time can coincide only in theory, as a rule in practice they don’t, machine elements have the same operating time. [1]

2. Methods of research

In agro-industrial production, machines and equipment have different operating time, for example, in crop production - seasonal, in cattlebreeding - year-round, which requires different approaches of machine organization and maintenance. Based on this, it develops a repair plan, calculates annual volume, and identifies the need for replacement parts, units, and materials. Farm specialists or service centers workers conduct maintenance of machines and equipment.

It found that the inputs efficiency to the use of one level of equipmentis different. Thus, operating $C$ and transferred $C + E_nK$ costs reduce to a certain value and further they increase, when inputs $E_nK$ given their norm coefficient $E_n$ in AD-100A and DAS-2B milking parlors(Figure 1).

![Figure 1](image)

**Figure 1.** Change of component costs $Z$- current expenses $C$ and inputs $K$ -on linear installations depending on their operating time $t$.

Such dependencies are characterized by the fact that the higher production inputs, the better their performance standards, and the lower the production cost. The annual reduction trend in the share of operating costs when using a particular machine is legitimate in cases when the machine is used in production and the conditions for the constancy of forms and method of organizing its operation according to the performance projections are maintained. Thus, the operating expenses structure changes by the increase of animal husbandry machines operating time [2]. The changes regularity of operating expenses component on the example of the TKP-70 store-loader for hay towers depending on the operating time is shown in Figure 2.
Figure 2. Depreciation charges change (K/t), valid ( ), average ( ), annual total C'(t), operation costs of the TKP-70 haylage towers depending on the operating time t (K – inputs, rub., – constant costs, rub., b – costs of maintenance and repair).

An important reserve of reducing operating costs and increasing the efficiency of using machines and equipment in animal husbandry [3] is the introduction of a routine-preventive system for maintenance and repair. The idea of the system is that regardless of the machine technical state after some time (scientifically based) according to the maintenance, farms that have a low coverage rates, the maintenance cost per one service quickly increases, and then it slows down with increasing λ. This connection is characterized by hyperbolic dependence:

\[ y_\lambda = 25.3 + 7.3/\lambda \text{ if } 0.17 \leq \lambda \leq 0.9 \]  

(1)

where – the cost of one periodic maintenance of line milking plants, rub.

The obtained value of correlation coefficient (r = 0.75) indicates a high linkage between studied traits [4]. The average cost of one periodic maintenance of all milking parlors deviated from the maintenance average cost by 800 rubles. This difference is because a significant gap in the maintenance conducting leads to premature equipment wear and parts damage, and an increase of remedial measures cost. With the increase of the λ coefficient, the technical readiness coefficient Rr of machines and equipment increases, and consequently, the effectiveness indicator — labor intensity (an hour per 100 kg) of producing milk. This dependence is described by the following equation:

\[ y_x = 14.03 - 4.94\lambda - 6.82R_t \]

(2)

We determined the R coefficient of multiple correlations, which was 0.967 for identifying the effectiveness indicator tightness with both factors. To determine the influence on studied indicator (λ or Rr), we found the private elasticity coefficient E, which characterizes the percentage of average changes of the analyzed indicator with a change of 1% of each factor at the fixed position of others:
$E_A = 0.44; E_{A_p} = 0.34$. It follows that the $\lambda$ coefficient has the greatest influence on dairy production labor intensity.

An important requirement for improving the efficiency of technical maintenance of machines and equipment - planning their maintenance and repair [5, 6]. Therefore, before the planned period, the farms' engineering service draws up an annual plan of animal husbandry machines maintenance and repair, in which they consider all machines of the farm. The machine technical condition at the beginning of the planned year is the initial data for the annual plan development (machine operation time from the last repair or the first operation), the planned operation time of the machine by quarters or months, and the frequency of maintenance and repairs [7]. Data on machine operating time is determined by chronometer or by time detector N-30 or N-348. It can be used the electric counters for the SCHR-TS1 operation time or another type of counter, which automatically starts and stops along with the machines and equipment. Sometimes single-phase power counter is used together with an incandescent light switched to the machine electric drive; the counter corresponds to the machine's operation time in hours. You can also use the calculation method based on the required volume of work and the machines output per shift. Accounting of machine operating time is necessary to control the equipment use in production lines during the day, which allows to properly organize maintenance. For example, knowing machines operating time, it is possible to timely conduct all operations of maintenance and control their frequency for equipment used in a unit technological complex (the maintenance frequency must coincide or be a short periodicity of the entire complex) [8]. At the same time, the frequency of the machines maintenance should be lower than the operating time average value at least than the value - deviation from its average values. Therefore, it is necessary to observe the maintenance precautionary conditions:

$$T_{mn} \leq T_{mn} - \Delta T_o$$

It is possible to determine the need for each machine maintenance and repair by analysis, nomograms, and graphic methods knowing the MC frequency and the machines annual time. In the first case, the need for each machine maintenance and repair:

$$N = (B_o + B_p) / T - N_p$$

(3)

where $N$ - the number of types of maintenance and repairs; $B_o$ - machine time from the last MC or repair, h; $B_p$ - planned machine time for the estimated year, h; $T$ — periodicity execution of the MC or repair for which the calculation is issued, h; $N_p$ - the number of all types of MC or ongoing repairs with a high frequency of the MC type or repairs for which the calculation is estimated.

The calculation is conducted in such sequence: firstly, it determines the required number of repairs, then the number of MC-2 and MC-1. When calculating the required number of repairs, the value is $N_p = 0$. The $N$ value is always rounded to the nearest whole number, mostly to downward, despite the fractional part. The value $B_o$ is remained as balance obtained by dividing the time from the last repair or the beginning of operation by the periodicity of the type of maintenance or repair on which the calculation is conducted. Thus, if refrigeration units and equipment of primary milk processing from the beginning of operation worked 2190 h, in this case, $B_o = 30$ h.

For the efficient operation of livestock farms equipment under the maintenance routine-preventive system, it is needed the appropriate production base, the basis of which is the maintenance centers (MC). Under the conditions of unified engineering service, the MC of farms are branches of district maintenance centers of livestock machines.
However, projects of livestock farms reconstruction do not always provide constant maintenance centers. Therefore, it is important to determine what reconstructed farms and complexes are needed. We found that the criteria of the maintenance center replacement at farms and complexes are the minimum of the spent and transport costs:

$$C_{\Sigma} = C_E + E_a K_c + C_{tr} \rightarrow \min$$  \hspace{1cm} (4)

where $C_{\Sigma}$ - total costs for maintenance, rub.; $C_E$ - expenses for machines maintenance and repair, rub.; $K_c$ - capital investment in the construction of maintenance center, rub.; $C_{tr}$ - transport expenses, rub.

The dependence of expenses level on the machines maintenance and repair is linked to the size of livestock farms and expressed by the following equation:

$$C_E = a_0 + a_1/N_{an}$$  \hspace{1cm} (5)

where $a_0$ and $a_1$ - coefficient of reserve and cost improvement limits on maintenance; $N_{an}$ - animal numbers on the farm.

Capital investments can be reduced due to cost cuts on construction and mounting works, and equipment installation in the maintenance center. In general:

$$K_c = A/N_{an} + B,$$  \hspace{1cm} (6)

where $A$ and $B$ are the coefficient of reserve and capital investment reduction limits.

Transportation costs:

$$C_{tr} = a' + b'R,$$  \hspace{1cm} (7)

where $a'$ and $b'$ - parameters of the line; $R$ - radius of service a livestock complexes, km.

If we know the cost of maintenance center and repair per animal $C_i$ (rub.) and $N_{an}$ number animals on the farm, then the total cost of maintenance center and repair per shift on one farm: $a_i = C_iN_{an}$.

3. The main part

Projects of livestock farms reconstruction do not always provide permanent maintenance centers. Thus, it is important to determine what types of reconstructed farms and complexes such points are needed. We find the radius (R) of maintenance of livestock farms and complexes according to the formula:

$$R = \sqrt{3C_iN_{an}/\pi\delta\eta'_d\eta'_bS_{tr}}$$  \hspace{1cm} (8)

where $\delta$ - the density of farms in the zone calculated per 1km$^2$; $\eta'_d$ - the coefficient of curve road routes; $\eta'_d$ - the coefficient of paved roads; $S_{tr}$ - transport costs, rubles per 1 km.

Substituting the expressions (2), (3), (4), (6) in (1) and differentiating by $N_{an}$ we get:

$$\frac{d}{dN_{an}}\left[ a_o + a_1 N_{an}/E_a A + B \right] + C_i \sqrt{\frac{3C_jN_{an}}{\pi\delta\eta'_d\eta'_bS_{tr}}} = 0$$  \hspace{1cm} (9)

After transformations:

$$N_{an} = \sqrt{\frac{9(a_1 + E_a A)^3\pi\delta\eta'_d\eta'_bS_{tr}}{(b')^3C_i}}$$  \hspace{1cm} (10)

It is possible to determine the size of the reconstructed livestock complex for which it needs to build a maintenance center. Thus, if for dairy farms $a_i=4249.76$; $A=15887.6$; $a_i=11.69$ rubles [9];
δ=0.01; \( S_t = 0.06; \eta'_t = 1 \) (for territories that have an ellipse shape with the ratio of half-axes, equal to 0.8); \( \eta''_t = 0.5; \ b' = 0.264; \ E_n = 0.15 \), livestock farm size \( N_{an} = 327 \) animals.

The size of livestock complexes, for which it is necessary to build a maintenance center, is significantly affected by their density (δ) in the zone. Calculations on the computer [10] showed that with growth δ the size of farms increases. For example, δ=0.05; δ=0.1; 0.2; 0.3; 0.4 and 0.5 (with unchanged values of other indicators) farm sizes are 489, 582, 692, 766, 823 and 870 animals respectively.

4. Conclusion
The routine-preventive system efficiency of the livestock machines maintenance significantly increases due to the specialization of engineering and technical service. The engineering service in animal husbandry is divided into two separate sections of technical operation, repair, and installation. The first section is responsible for all installed equipment efficient use, and the second section is responsible for installation, adjustment, and repair.

Farmers that have small livestock farms and for those full set of expensive equipment is cost-ineffective, they can use them based on cooperation. The supply service provides a centralized procurement of replacement parts, exchange fund of assemblies and units, new equipment. The farms established production departments, which included chief engineers (managers of departments), accountants, fixers, and repair workers. The economy of repair and maintenance work is paid at cost with the accrual of savings in the amount of 5%.

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