Study of the efficiency of using a machine in the automation of agricultural production

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Abstract. The past period of economic and agrarian reforms has shown that actively applied measures to radically change production relations have not yet yielded positive results, since the mechanism for creating the appropriate productive forces, and especially from the active technical part, has not been developed. The need to improve management methods in the field of equipment operation is dictated by the deepening contradictions of an economic, technical and environmental nature. They can only be resolved through a systematic approach. The article provides an analysis of the development of interrelated complex and differentiated standards for the need for material, labor and other resources for various levels and modes of planning.

1 Introduction

The solution of large and complex problems associated with the automation of agricultural production requires strict coordination of the work carried out by numerous scientific institutions. The first step in this direction should be the development of a unified long-term plan for scientific research, taking into account the achievements of science and the experience of automating various branches of production. Process modeling makes it possible to study the possibilities of using numerical methods for modeling the interaction of the soil environment and the working bodies of tillage machines [1-5,11].

When training engineering personnel, the issues of system justification of decisions are not given due attention, therefore, it is necessary to define some important concepts for further presentation [2,7].

The rational use of non-renewable resources (materials, fuel, time, etc.), the reduction of harmful effects on the soil should be taken as the basis for the environmental activities of the engineering service.

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Of particular note is the ability to assess the role of engineering services in the final results of production using environmental performance indicators. Characteristic is the coefficient of energy efficiency of technologies:

$$K_E = \frac{E_{me} + E_{ec}}{\sum E_{nr}}$$  \hspace{1cm} (1)

where $E_{me}$ and $E_{ec}$ are the energy equivalents of the yield of the main and additional products, MJ; $E_{nr}^j$ – costs of non-renewable energy, including energy equivalents of the applied equipment and technological materials, MJ.

The introduction of resource-saving technologies and the corresponding complexes of machines reduces the value of the denominator in formula (2), and the timely and high-quality performance of mechanized work, the elimination of crop losses increases the value of the numerator. As a result, the value of KE increases significantly. The loss of the final product is the irretrievable loss of all resources spent on its production.

2 Results and discussion

Considering the construction process as a complex system, including the construction object, building materials, machines and performers, it is possible to divide the work object into a number of dispersed sub-objects, characterizing the volumes and technological conditions of work. Transport links between these sub-objects are represented by distances and conditions of movement of vehicles, their speed, maneuverability and other factors. The changeable operational productivity of the machine is determined by the expression [3].

$$P_s = \frac{V_s}{t_s}$$  \hspace{1cm} (2)

where $V_s$ is the amount of work performed during the shift; $t_s$ – shift time. Taking into account the dispersal of objects, the amount of work performed per shift:

$$V_s = \sum_{i=1}^{n} V_i$$  \hspace{1cm} (3)

where $V_i$ is the amount of work on the i-th sub-object; $n$ is the number of sub-objects.

The shift time $t_s$, in turn, consists of the time $t_0$ of the machine run from the base of mechanization to the object at the beginning of the work shift and back at the end of the shift, the time $t_0$ of work at the object and the time $t_{mov}$ of moving from one object to another.

$$t_s = t_0 + t_p + t_{mov}$$  \hspace{1cm} (4)

Run time from the base of mechanization to the object and back:

$$t_0 = \frac{l_0}{v}$$  \hspace{1cm} (5)

where $l_0 = l_{01} + l_{02}$ is the total distance from the mechanization base; $v$ is the average transport speed of the base machine. Hours of operation at the facility:

$$t_p = \frac{V_s}{P_{op}}$$  \hspace{1cm} (6)

where $P_{op}$ is the operational performance; $P_{op} = P_{tech}k_b$; $P_{tech}$ – technical productivity.

Time to move the machine from one sub-object to another

$$t_{mov} = \frac{l_{i+1}}{v}$$  \hspace{1cm} (7)

where $l_i$ is the distance between the $i$-th and $i+1$-th sub-objects. In general

$$t_s = t_0 + t_p + \sum_{i=1}^{n-1} V_i$$  \hspace{1cm} (8)

Given that $vt_s = l_{max}$ is the maximum possible mileage during a shift, the last expression can be represented as:

$$k'_{ls} = \frac{P_s}{P_{op}} = 1 - \frac{\sum_{i=1}^{n-1} l_i}{l_{max}}$$  \hspace{1cm} (9)

where $k'_{ls}$ is the theoretical coefficient of use of machines over time during the shift. Analysis of the obtained expression shows that the efficiency of using the machine during the shift
depends on the distance between the work object and the mechanization base and on the number of sub-objects. The following special cases can be assumed:

1. The car has no haul runs during the shift

\[ l_0 + \sum_{i=1}^{n-1} l = i ; K_{t,s} = 1; P_s = P_{op} \]

2. The car is busy driving to the facility during the shift

\[ l_0 + \sum_{i=1}^{n-1} l_i = i \ max; k_{t,s} = 0; P_s = 0 \]

Thus, the coefficient \( k_{t,s} \) has real values within \( 0 < k_{t,s} < 1 \) and, accordingly, the shift productivity has limits \( 0 < P_s < P_{op} \). However, the obtained coefficient \( k_{t,s} \) and shift productivity of the machine from the amount of work on sub-objects.

The amount of work performed per shift can be expressed as:

\[ V_s = nV_{av} \]  

(10)

where \( V_{av} \) is the arithmetic mean of the amount of work per sub-object. If the average volume of work is \( X_{av} = k_u V_{max} \), where \( k_u \) is the relative average volume; \( V_{max} \) is the maximum possible amount of work performed by the machine during the shift, \( V_{op_{s_{max}}} \), then \( n = \frac{k_{t,s}}{k_v} \). Distance between subobjects

\[ \sum_{i=1}^{n-1} l_i = (n - 1)l_{av}, \]

where \( l_{av} \) is the arithmetic mean of the distance between subobjects. Respectively:

\[ k_{t,s} = \frac{10_{av_{max}}}{l_{av}} \frac{k_{max}}{k_v} \]  

(11)

This expression allows you to determine the efficiency of using the machine in terms of time during the shift, depending on the distance of the mechanization base from the work object, the distance between sub-objects, as well as on the amount of work on sub-objects, expressed by the relative average single object \( k_v \).

When performing dispersed small-volume work, it is usually sought to complete entire volumes of work at sites during a shift, which is advisable in terms of saving the cost of moving the machine. In this case, the actual coefficients \( k_{t,s} \) of machine usage by time \( k_{t,s} \leq k_{t,s} \). Taking into account the restrictions that determine the need for the completed execution of an integer number of unit volumes of work at the facility, \( n = 1; 2; 3; ...; j \). The actual coefficient of use of the compactor over time \( k_{t,s} = nk_v = k_v; 2k_v; 3k_v; ...; jk_v, \) where \( j \) is any integer of the number series.

The last equality is valid in the case when the shift time of the machine is used for all the specified operations without a trace or there is no need to perform a whole number of unit volumes of work. Depending on this, the replaceable coefficient of use of the machine in time is found according to a theoretical dependence or after determining the coefficient \( k_{t,s} \), it is necessary to find the number of objects \( n \), round it down to a whole number, and then find the actual coefficient \( k_{t,s} \).

Figures 1 and 2 show the plots of the theoretical (a) and actual (b) time utilization of a hydraulic excavator with a hinged segmental working body [4] for compacting backfill soils in hard-to-reach places during a shift from measurements of the average distance \( l_{av} \) between dispersed objects.
Analysis of the graphs shows that the theoretical machine utilization by time during a shift has an inverse exponential dependence on the run length. With an increase in the average distance between objects, the theoretical coefficient $k_{t,s}$ decreases and, consequently, the shift productivity of the machine decreases. The actual coefficient $k_{t,s}$ has a step. (piecewise-continuous) exponential dependence, which is determined by adjusting the theoretical curve taking into account an integer number of dispersed objects of work. At the intersection points, the expressions $k_{t,s} = k_{t,s}$ are valid, that is, with the corresponding values of the mileage $L$, the number of objects $n$ and the relative average unit volume $R_u$, the entire shift time of the machine is entirely used for technological operations and the necessary transport machine movement [1-10,12].
The efficiency coefficient (E) makes it possible to coordinate the centralized selection of measures and technical means to reduce the cost of production with national economic interests. The greatest effect from its reduction corresponds not to the minimum, but to the optimal value of the cost of each type of product, which is possible at the lowest reduced costs:

\[ C = T + \sum_{i=1}^{n} K_i E, \]  

where \( C \) is the sum of the reduced costs, rub.; \( T \) - the value of current costs in this production, rub.; \( K_i \) is the value of the \( i \)-th type of resource used, rub.

The above costs act as an economic category, reflecting the value (in value terms) of the total costs of social labor, as well as current and one-time costs for the production of products. Ensuring the minimum value of these costs meets all the requirements of the national economic approach to cost reduction, since it decreases in cases of saving current (\( T \)) and capital investments (\( K_i \)), attracting additional funds, which is justified by the amount of savings in current costs. Inclusion in the sum of the reduced renovation costs and the efficiency factor is economically justified. The deductions for renovation represent the loss of value of specific means of labor. They do not return resources to the national economy, but only funds to the enterprise to replace retired equipment. The efficiency coefficient characterizes the amount of additional costs in other areas, due to the fact that part of the accumulation fund is spent on the creation of means of production.

The optimization of the composition of technical means should be based on economic prerequisites: ensuring equal or greater profitability from the use of existing equipment and machines that replace them, the implementation of production processes in optimal agrotechnical terms.

Like other social phenomena, the system of machines is being improved in accordance with the dialectical laws of the development of material production with its inherent general laws:

- in the transition from one system to another, society does not immediately destroy the technology that was created in the previous period, but uses it at a certain stage;
- the improvement of technology proceeds through the transition from slow quantitative changes to fundamental qualitative ones.

3 Conclusion

Thus, a refined assessment and forecasting of shift productivity when performing small dispersed amounts of work can improve the accuracy of operational planning and rationing of such types of work and reduce intra-shift downtime of machines to a minimum. A more accurate forecast is possible taking into account the topology of the serviced work site and the conditions of the transport movement of the work. To develop an interconnected set of differentiated standards for the need for material, labor and other resources for various levels and modes of planning, it is necessary:

- specify the required number of representative farms for each zone;
- by joint efforts of interested departments to create an appropriate computer program;
- solve a number of organizational and financial issues for the performers;
- to ensure the stability of (permanently) selected representative farms as pilots for the development, implementation and testing of a normative method of planning.

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