Application of Tools of the Technical Diagnostics System to Increase the Efficiency of Mobile Equipment in the Agro-industrial Complex in the Conditions of Sustainable Development

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Abstract: the trouble-free performance of planned works by agricultural machinery both during the periods of sowing and harvesting companies, and the performance of daily work. The problems considered in the work are related to the fact that at the regional level there is a significant variation in the agricultural equipment used, both by brands, types and production times of this equipment. In such conditions, it is rather difficult to use a unified approach to conducting technical diagnostics, and the range of natural, climatic, and soil conditions only complicates the task of developing the optimal option. The paper analyzes the survey of self-propelled machines in the Omsk region farms located in different natural zones, assesses the system of technical diagnostics in farms, formulates proposals for a strategy for developing technical diagnostics at the regional level.

1 INTRODUCTION

A global trend is the saturation of the agricultural industry with sophisticated energy-efficient mobile equipment with a simultaneous decrease in the number of workers employed in the industry (MacDonald, 2015). Under these conditions, the overall efficiency of the economy, which includes both economic efficiency and the organization of work, depends on the readiness of the technical support complex.

In (Silva, 2019), it is noted that maintenance is becoming one of the main functions of agribusiness enterprises and is included in strategic assets that increase their competitiveness.

Taking into account the widespread introduction of digital and intelligent technologies in agriculture, it is necessary to formalize the process of assessing the readiness of a complex of machines. It is possible to describe the readiness of a complex of machines of a particular farm by the readiness factor, which can be set by a number of parameters:

$$K_g=\{T_o, P, Z, D_t\} \quad (1)$$

where T_o is the vector of the technical condition of machines, P is the assessment of personnel readiness, Z is the vector of the availability of spare parts and operating materials, and D_t is the system of technical diagnostics.

The technical state of an object (machine), including a mobile one, is a state that is characterized at a certain point in time, under certain environmental conditions, by the values of the parameters established by the technical documentation for the object (GOST 20911, 1989).

The types of technical condition according to (GOST 25044-81, 1983) are: serviceable, efficient, defective, inoperative, depending on the values of the parameters set in the technical documentation for the machine, at a given time.

Thus, the vector of the technical state of a complex of farm machinery can be specified at a certain time by the vector

$$T_o=\{s_1, s_2, s_3,..s_n\} \quad (2)$$

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where $_{si}$, takes one of the values "faulty, faulty, operable, inoperative", i = 1, n, n is the number of agricultural machines on the farm.

The task of analyzing the influence of the parameter "readiness assessment

personnel ", on the readiness of the complex of machines, however, it is obvious that the rest of the indicators depend on it, both directly and indirectly.

The parameter of availability of spare parts and operating materials can be set at a certain moment in the form:

$$Z=\{z_1, z_2, z_3,..z_n\} \tag{3}$$

where z_i, is determined as a percentage of the required value, i = 1,n, n is the number of agricultural machines on the farm.

According to (GOST 20911, 1989), a system of technical diagnostics (monitoring of technical condition) is a set of tools, an object and performers necessary to carry out diagnostics (control) according to the rules established in technical documentation.

The D_t farm technical diagnostics system should solve the problems defined in (GOST 25044-81, 1983):

- determine, with a given probability, the technical condition of the i-th machine;
- to identify critical defects that change the technical condition of the i-th machine;
- to predict the time interval of changes in the technical state of the i-th machine.

The assessment of the system of technical diagnostics of a certain economy can be based on the possibility of solving the above problems.

We define the type of technical diagnostics system as C_1, if the farm has created conditions for solving problem 1, C_2, if conditions are created for solving problems 1 and 2 and C_3, if conditions are created for solving problems 1-3, C_0-in the absence of conditions for solving tasks 1-3.

Let us determine how the systems of technical diagnostics C_0-C_3 are implemented, it is obvious that this implementation depends on the type of equipment used.

Figure 1 shows the classification of technical diagnostics systems, depending on the equipment of the self-propelled vehicle with the means of internal diagnostics implemented by digital devices.

Let us consider how the types of technical diagnostics systems are combined with the strategies for the maintenance and repair of machines (MRO) identified in (Lebedev, 2019).

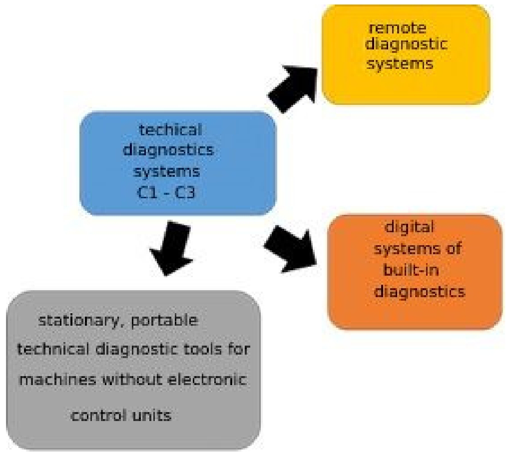

Figure 1: Classification of technical diagnostic systems.

The strategy of reactive maintenance (RM) on demand - carrying out maintenance and repair in cases of the machine's transition to an inoperative state, is obviously implemented with the C0 and C1 diagnostic systems.

The preventive maintenance (PM) strategy for operating time and scheduled maintenance is also implemented with the C0 and C1 diagnostic systems.

A condition based maintenance (CBM) strategy will require a C2 diagnostic system.

Predictive maintenance (PdM) strategy Predictive maintenance and reliability centered maintenance (RCM) reliability maintenance will require a C3 diagnostic system.

Currently, farms producing agricultural products use a complex of mobile equipment of Russian and foreign production without electronic control units, modern Russian and foreign equipment with electronic control units and built-in diagnostic systems. And the problematic at the regional level for Russian conditions is the absence of a unified strategy for technical diagnostics of mobile agricultural machines.

2 MATERIALS AND METHODS

The Omsk region is one of the most developed agricultural regions of Siberia. The region provides The region provides more than 3% of the all-Russian volume of state grain purchases. The share of crop production is up to 40% of gross agricultural production, including grain crops - 15-20%, fodder crops - 10-15%. Thus, the level of development of the agro-industrial complex, including the technical equipment of crop production, has a significant impact on the socio-economic situation of the region

(Order of the Government of the Omsk Region, 2020).

The paper presents studies carried out in various agricultural enterprises of the region in order to determine the types of applied technical diagnostics (TD) systems, assess the effectiveness of the applied TD systems and the possibility of developing a unified territorial approach. For the study, methods of measuring the parameters of mobile equipment were used in order to determine its condition, the survey method of farm workers and statistical processing of the results.

The territory of the Omsk region covers the following natural zones: forest, forest-steppe and steppe, each of which is further subdivided into subzones. Each natural zone is characterized by its own conditions due to the latitudinal distribution of heat and moisture, which affect the possibilities and efficiency of farming (Aleshchenko, 2013).

Figure 2 shows the territorial division of the Omsk region into natural zones, and Figure 3 shows the distribution of agricultural sown areas.

Figure 2: Natural zones of the Omsk region.

On the territory of the region, there are more than 10 agro-soil regions, more than 50 soil varieties in arable land. These circumstances cannot but influence the choice of agricultural machinery for crop production. As noted in a study conducted in (Boyko, 2018), the reduction in unit costs largely depends on the introduction of resource-saving and agro technologies in crop production, which also depend on the technical re-equipment of farms.

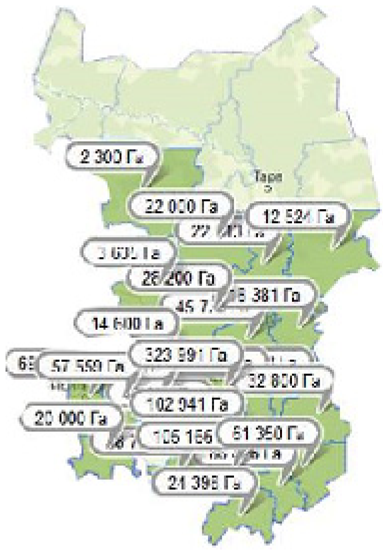

Figure 3: The area of farmland in the Omsk region.

To study the applied TD systems and assess their effectiveness, commodity producers from various natural zones were selected, with a tractor fleet of at least 10 units and a fleet of grain harvesters of at least 5 units, used for the production of work in crop production.

To determine the initial technical state of the mobile equipment of the farm, diagnostic measures were carried out with the measurement and recording of both direct and indirect indicators, such as: engine oil pressure, injector pressure, compression in cylinders, engine oil quality, exhaust smoke. Further, the same parameters were measured during spring and autumn works and before the conservation of equipment for the winter period. The study of the quality of engine oil on the basis of samples taken from the engines was carried out in a certified laboratory.

The main task of the analysis of the measured values of diagnostic parameters was to determine the type of technical diagnostics system used by the farm and to form the trajectory of the operation of the mobile device.

The formation of the trajectory of the operation of the mobile device consisted in determining the current technical condition, assessing the residual resource and calculating the forecast of critical events.

In the process of determining the type of TD system, the economic effect that the economy could receive from changing the type of TD system was calculated.

3 RESULTS

Table 1 shows the economic entities selected for the study.

Table 1: Mobile equipment of selected farms in different natural areas.

Zone / territorial area	Mobile equipment (Recommendations for the diagnosis of the technical condition of agricultural machinery, 2020)
Northern forest-steppe / Bolsherechensky	Tractors { KIROVETS K-701, KIROVETS K-700A, MTZ-80, MTZ-82.1} Combine harvesters { KZS-812 "PALESSE GS812 (2), UES-280" PALESSE U280, CLAAS TUCANO 430}
Stepnaya / Cherlaksky	Tractors {CLAAS AXION 850, CLAAS AXION 950, MTZ -80 (2)} Combine harvesters {CLAAS TUCANO 450 (3), CLAAS TUCANO 570}
Stepnaya / Cherlaksky	Tractors {MASSEY FERGUSON MF8737, CLAAS AXION 900, MTZ 80, MTZ 1221} Combine harvesters { ACROS 550, VECTOR 410, VECTOR 430 CLAAS TUCANO 570}
Southern forest-steppe / Omsk	Tractors { KIROVETS K-701 (2), MTZ 82, MTZ 80, T-150} Combine harvesters { KZS -812 (3), KZS -7 (2)}
Podtaezhnaya / Znamensky	Tractors {BUHLER VERSATILE 2375, NEW HOLLAND T8040, MTZ 82, MTZ 1221.2} Combine harvesters { KZS -812 (2), KZS -7 (3)}

As follows from Table 1, farms, as a rule, use various mobile equipment, both by model, manufacturer and year of manufacture. Note that, despite the difference in natural zones noted above, farms use the same type of machines.

Table 2 summarizes the data on the mobile devices used on the farms.

In the conditions of a significant spread in the brands, models and years of production of mobile devices, shown in Table 2 for one of the surveyed farms, and a similar picture is observed in others, it is very difficult and costly for farms to provide diagnostics and maintenance of all equipment used.

For mobile devices without built-in diagnostics, it is necessary to have a set of technical tools and a specialist, for new generations of mobile technology, as a rule, third-party services are used. As a rule, such organizations are located in the regional center, which for remote areas, in emergency cases, does not provide sufficient service.

Table 2: Characteristics of mobile equipment used on farms.

Mobile equipment	Параметры
Tractor MTZ -80	Engine {D-240} Year of issue {1990} Running time, m / h {10500}
Tractor KIROVETS K-701	Engine {ЯМЗ-240 БМ } Year of issue {1986} Running time, m / h {250}
Трактор KIROVETS K-700A	Engine { ЯМЗ-238 НД } Year of issue a {1990} Running time, m / h {180}
Combine harvesters KZS 7 « PALESSE GS 07»	Engine { Д-260.4} Year of issue {2011} Running time, m / h {1680}
Combine harvesters KZS -812 « PALESSE GS812»	Engine {Д-260.4} Year of issue {2009} Running time, m/h {1700}

Based on the indicative data collected in farms, the distribution of the number of mobile assets for which farms use one or another TD system, shown in Figure 4, has been constructed.

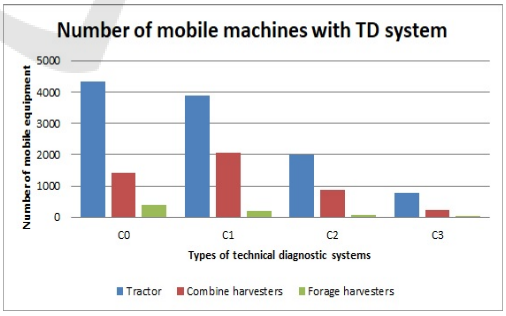

Figure 4: Diagram of the distribution of TD systems.

The diagram of the distribution of the availability and use of diagnostic systems in farms reflects the real picture at the regional level. A significant number of mobile equipment that has already exhausted its resource (according to various estimates, about 60%), a large percentage of equipment from foreign manufacturers with a significant service life does not contribute to the transition to C_3 diagnostic systems, and the use of modern PdM and RCM maintenance strategies. The most widespread in farms is diagnostics by organoleptic indicators and routine maintenance, which, as studies show (Komarov, 2018), are the reason for the low MTBF.

4 SUMMATION

The conducted studies have shown that farms in the region lack a strategy for the formation of a complex of mobile means for performing work in crop production.

Research and statistical data (Analytical report, 2016) show that the region's farms are dominated by mobile equipment from foreign manufacturers. The operation of foreign equipment in each region has a number of features that impose their own requirements on the organization of the technical diagnostics system, in particular:

- mobile equipment of foreign manufacturers, as a rule, has a higher reliability, and as a result, a significant operating time. The high cost of such equipment increases the economic losses of the economy in the event of its breakdown and shutdown, this makes special requirements for diagnostics and maintenance (Gabitov, 2007);
- as a rule, the farm cannot carry out diagnostics of foreign equipment on its own, but only with the involvement of specialists from specialized enterprises or dealers of this equipment, which worsens the overall logistics of the farm.

At the same time, the economic policy of the state aimed at subsidizing the purchase of domestic equipment has led to its growth in farms (Analytical report, 2016). However, the reliability of this technique is lower than that of foreign counterparts, which also significantly increases the requirements for technical diagnostics, maintenance and repair and forecasting of the residual resource.

5 CONCLUSIONS

A significant number of works, both Russian and foreign authors devoted to the development of new tools for CIP technical diagnostics, show the relevance and importance of this topic.

New diagnostic tools have increased requirements for the accuracy of measuring the diagnosed parameters, a high probability of detecting defects that can lead to critical breakdowns. The development of new tools goes in several directions:

- modernization of already used diagnostic tools, with the possibility of connecting a computer and the possibility of computer processing of the results (Livshits, 2010), with the possibility of using it for machines without electronic control units;
- the development of developed specialized software and hardware, which allows not only to identify failures in a mobile device, but also to predict the failure time and estimate the required repair time (Silva, 2019);
- the development of remote diagnostics and monitoring technologies that allow not only to control the parameters of a mobile device, but to collect information on non-productive use, optimal movement, etc.

However, many of these funds will be inaccessible to small farms, with the absence of their own diagnostic and repair facilities, with the lack of qualified personnel and a variety of equipment, both by type and model. In these conditions, the optimal solution seems to be the formation of a strategy at the regional level, which should:

- to stimulate farms to get rid of outdated models of mobile equipment, with excess operating time;
- to stimulate the development of exemplary complexes of mobile equipment for plant growing, corresponding to the natural, agro-climatic, soil conditions of farms; - to stimulate the creation of a regional center for digital technologies to ensure the conduct of technical diagnostics, the development of remote diagnostics systems.

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