Evaluation of the main indicators of the reliability of the power transmission of a combine harvester John Deere 9660

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Abstract. The failure-free performance of the components determines the technical and economic efficiency of the use of the combine harvester. A low level of reliability leads to an increase in the cost of harvesting, the need for unscheduled repairs due to failures of parts, assemblies and assembly units. Studies have shown that a significant proportion of failures occur in power transmission units. In this regard, the aim of the work is to assess the reliability of the power transmission of the John Deere 9660 combine harvester. The average time between failures of the power transmission units was 80 hours, which does not meet the regulatory requirements (according to STO AIST 8.22 - 2010 - at least 100 hours). Failures of all powertrain assemblies are caused by a combination of failures: wear and fatigue failure of the bore holes for the bearings of the unit housings, and gears, bearings from dynamic loads.

1 Introduction

The power train of the John Deere 9660 combine harvester consists of a drive axle, final drives and a range box. The importance of assessing the reliability of power transmission is confirmed by a significant number of studies aimed at improving the reliability of agricultural machines [1,2].

The longevity of the elements of combine harvesters is of great importance, since the yield and grade of cultivated crops largely depends on the implementation of the relevant work within the agrotechnical time frame. It should be noted that only recorded and taken into account machine downtime for harvesting crop products account for up to 50% of the total working time of the combine harvester. This indicates the lack of reliability of agricultural harvesting equipment and maintaining it at the proper level during operation and repair. In addition, downtime is associated with insufficient provision of machinery and equipment with spare parts, and their rational use [3].

The power train is one of the most unreliable, systematically failing combine harvester systems. As practice shows, in terms of failure frequency, the power transmission takes the third place among all units and assemblies of the John Deere 9660 combine harvester. The average time to eliminate the failure of the drive axle, range box, final drives, in relation to other units of the John Deere 9600 combine is the longest. The most complete use of the technical resources of the components and assemblies of the power transmission, the timely execution of maintenance work with the minimum labor and materials
costs, largely depends on how well the operations on replacing and restoring resource elements are worked out in the machine.

2 Materials and methods
The acquisition of new equipment, including foreign production, is impossible without an analysis of the initial indicators of reliability, durability, maintainability and the rate of change during operation.

Such researches make it possible to obtain general patterns of change in characteristics, to establish their quantitative indicators, on the basis of which to identify and disclose design flaws.

An analysis of these patterns allows us to develop specific recommendations for improving the efficiency of using existing machines.

With this in mind, the objectives of the study are:
1. Determination of failure-free performance indicators of power transmission units of a John Deere 9660 combine harvester;
2. A quantitative assessment of the reliability indicators of units and power transmission units.

At the stages of experimental testing, testing and operation, as a rule, the role of reliability indicators is performed by statistical methods for assessing the corresponding probabilistic characteristics. All reliability indicators, in accordance with GOST 27.002-2017 [4], are defined as probabilistic characteristics. In the work, the failure of the object is considered as a random event, that is, the given structure of the object and the conditions of its operation do not determine exactly the moment and place of occurrence of the failure. The adoption of this more widespread concept predetermines the widespread use of probability theory [1,2,4,5,8].

Reliability indicators are regulated by observation plans. To assess the reliability of power transmission reliability, the observation plan [N, R, T] is the most acceptable. Its use is justified by the minimum time spent on the experiment. The observation plan [N, R, T] provides for the assessment of the following reliability indicators:
- average time to failure;
- mean time between failures;
- average resource.

To calculate the parameters of the distribution law to failure, the first two types of operating time can be used equally if the products are replaced with new ones, as well as with the full restoration of all operating parameters after repair. Information on developments of the third type can also be partially used.

The procedure for collecting information on the reliability of facilities, the forms for recording and accumulating data on malfunctions and failures are defined in GOST 27.502-83 and RD 50 - 204 - 87 “Collection and processing of information on the reliability of products in operation”.

Data collection about power transmission failures was carried out on the basis of: “Technical act on damage and malfunction of an assembly or unit”, “Combine maintenance record book”, on-board computer fault codes.

A group of 37 vehicles was placed under surveillance. During operation, we tracked the time between failures, recorded the time of the case of the failure, the time to restore the working state, the costs of restoring the working state (direct and indirect), the causes of failures, etc.

A special algorithm for fixing faults was developed for each series of combines [9, 10].

The algorithm consisted of a digital code, including: the node where the failure occurred, the failed part, the type of failure. The digital code generated in this way was recorded in a database and processed using a computer.

3 Results and discussion
According to the adopted observation plan [N, R, T], the following indicators are accepted as indicators: average resource, time to failure, time between failures [11,12].Figures 1-6 show function graphs illustrating the distribution of statistical failure indicators of power transmission elements.
$T_{cp}$ – mean time to failure;  
$F(T)$ - curve of accumulated experimental probabilities of operating time to failure;  
$f(T)$ - time-to-failure density functions

\[ f(T) = 3.0 \cdot 10^{-3} \cdot e^{-\left(\frac{T-75}{70}\right)}, \]
\[ F(T) = 1 - e^{-\left(\frac{T-75}{70}\right)}. \]

Figure 1. Graph of the density distribution function of running hours to failure and a curve of accumulated experimental probabilities of running time to failure of the drive axle of the John Deere 9660 combine harvester

\[ T_{cp_0} \text{ – mean time between failures}; \]
\[ F(T) \text{ - curve of accumulated experimental probabilities of running between failures}; \]
\[ f(T) \text{ - the density function of operation time between failures} \]
\[ f(T) = 0.77 \cdot 10^{-3} \cdot e^{-\left(\frac{T-18}{15}\right)}, \]
\[ F(T) = 1 - e^{-\left(\frac{T-18}{15}\right)}. \]

Figure 2. Graph of the density function of the distribution of running hours between failures and a curve of accumulated experimental probabilities of running time between failures of the axle drive axle of a John Deere 9660 combine harvester

\[ T = 25 \pm 14 \text{ h} \]
\[ \sigma = 20 \text{ h} \]
\[ V = 0.80 \]

Figure 3. Graph of the density distribution function of running hours to failure and a curve of accumulated experimental probabilities of running time to failure of the range box of a John Deere 9660 combine harvester

\[ T_{cp} \text{ – mean time to failure}; \]
\[ F(T) \text{ - curve of accumulated experimental probabilities of operating time to failure}; \]
\[ f(T) \text{ - time-to-failure density} \]
\[ f(T) = 1.4 \cdot 10^{-3} \cdot e^{-\left(\frac{T-25}{20}\right)}, \]
\[ F(T) = 1 - e^{-\left(\frac{T-25}{20}\right)}. \]
Failures of all powertrain assemblies are caused by a combination of failures: wear and fatigue fracture of gears, bearings from dynamic loads.
Thus, when operating a John Deere 9660 combine harvester, the low range box life should be considered. In addition to the main repair actions, it is necessary to plan additionally the maintenance and overhaul of this unit.

4 Conclusions
1. The work has developed and proposed an algorithm for recording failures in the power transmission of a John Deere 9660 combine harvester in the form of a digital code that allows identifying and classifying failures of power transmission units.
2. In this work, we obtained the functions of distributing the operating time between failures, the operating time to failure of the components and assemblies of the power transmission of the John Deere 9660 combine harvester.
3. Failures of all power transmission units are caused by a combination of failures: wear and fatigue failure of gears, bearings from dynamic loads.

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