Improving the efficiency of existing methods of diagnosing the hydraulic drive of road-building machines

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Abstract. The article presents modern methods of diagnosing hydraulic drive. The drawbacks of modern diagnostic methods are revealed. The negative consequences of the effect of stagnation of the working fluid. The results of studies of working fluid samples are given. Suggested ways to solve the existing problem. A method for determining the nodes subject to the effect of stagnation of the working fluid is proposed. The effect of solving the problem of stagnation of the working fluid is determined.

More attention is paid to monitoring the condition of the hydraulic drive of road-building machines, this is due to the desire to increase the service life of the hydraulic drive, as well as to minimize the number of unexpected failures of the hydraulic drive elements. In road construction machines, 70-90% of hydraulic failures are associated with contamination of the working fluid. [1] The service life of the hydraulic drive and the number of failures of its elements directly affect the final economic indicators of road construction machines, this is especially important for the operation of machines in countries with seasonality of construction work. Economic efficiency is one of the key parameters determining the cost of work. Reducing the cost of work will increase the profits of road-building companies, and the possibility of increasing profitability makes it important to increase the reliability and reliability of the hydraulic drive and its elements.

Today, there are many methods for monitoring the condition of the hydraulic drive of road-building machines. These diagnostic methods are based on the analysis of the elements of the hydraulic drive or on the analysis of the state of the working fluid. A prominent representative of the first group is the statistical parameter method; this diagnostic method determines the condition of the hydraulic drive by comparing the parameters of leakage, flow, pressure and efficiency of the hydraulic drive elements. Diagnostic methods based on the analysis of the state of the working fluid are based on the study of the working fluid for its purity. The purity of the working fluid is regulated by GOST 17216-2001, this standard defines 19 classes of purity of the working fluid, according to this standard, the working fluid is considered clean if it contains less than 0.064% of pollutants. Also important is the parameter of the acidity of the working fluid, determined by the number of milligrams of potassium hydroxide necessary
to neutralize all the acidic components contained in 1 gram of the working fluid, the maximum permissible value is 1.5 milligrams.

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Statoparametric method is widely used due to high efficiency, but for the operation of this method it is necessary to determine the main parameters of the hydraulic drive of a fully functional machine, and then compare the parameters with them. [2] Another advantage is the ability to determine the state of individual elements of the hydraulic system. [3] The disadvantages of the system are the need for expensive research equipment, the research process is also very labor intensive, and the need to introduce special equipment to the hydraulic system requires relocating the equipment to a clean room to prevent contamination of the system, Felix Angie, Jennifer Harding and Jacqueline Glass describe in their article problems on the diagnosis of hydraulic, faced by enterprises operating equipment in the field, also noted that this problem complicates economic planning and increases the number of unanticipated failures. [4] Technological progress is not in place, new diagnostic methods are replacing the old, more advanced and less labor-intensive. Methods of analyzing the state of the hydraulic drive based on the state of the working fluid are becoming more common in recent years, the company Caterpillar Inc. In their cars, she implemented an additional option, by which payment the enterprise operating equipment gets the opportunity to send samples of the working fluid to specialized laboratories. The laboratories analyze the working fluid, on the basis of which the frequency of replacement of the working fluid is determined, and on the basis of the contamination intensity of the working fluid and on the type of pollutant, the enterprise operating the machine is provided with information on the presence of an element in the system with increased wear. [5] In addition, the Hitachi EX5500-6 excavator implements a system for monitoring the state of the working fluid in real time.

Over time, the hydraulic drive of the road construction machines became more and more complicated; at present, this has led to the possibility of the emergence in the hydraulic drive of zones in which the direct functions of the working fluid are not performed. If there are nodes in the system that are distant from the hydraulic distributor, a situation may arise in which the working fluid will not be updated due to the fact that the volume of fluid in the pipeline is higher than the volume of fluid in the cylinder cavity. In connection with the complication of the hydraulic drive of the road-building machines, the question of the division of the hydraulic drive into zones with complete, partial and obstructed circulation of the working fluid is becoming increasingly important. The division of the hydraulic drive into zones will improve modern methods of diagnosing the hydraulic drive.
Figure 1 shows a simplified diagram with a hydraulic cylinder and a hydraulic distributor, in that case, if the volume of working fluid in the piston cavity (V1) is less than the volume of working fluid in the pipeline (V3), the process of updating the working fluid will be difficult. The main functions of the working fluid are lubrication of rubbing surfaces, cleaning from wear elements, as well as heat dissipation. In case of problems with the circulation of the working fluid, respectively, there are problems with the lubricity, cleaning and cooling functions of the working fluid, this in turn can lead to a serious reduction in the resource of remote elements of the hydraulic drive.

Over time, not only diagnostic methods and hydraulic actuators are improved, but also hydraulic fluid. Modern hydraulic fluid incorporates many additives that have anti-corrosion, anti-foam, anti-oxidant properties. In the event of a stagnation effect of the working fluid, the additives will more quickly deplete their resources, as a result of which they will lose their properties, which in turn leads to a further reduction in the life of the hydraulic drive elements. [6] In addition, possible inclusions of inclusions designed to improve the properties of the working fluid in the sediment, respectively, increasing the degree of contamination of the working fluid.

To verify the existence of this effect, sampling of the working fluid from the HBM TG190TA-4 grader was made. The working fluid was replaced in April 2018, sampling was carried out in March 2019, the motor grader produced 3,000 machine hours, in the summer the motor grader was involved in road construction works, in the winter period road maintenance works were carried out, the dozer was accounted for about 5-10% of the work. Samples were taken from the piston cavity of the main blade and from the rod cavity of the bulldozer blade, this was done in order to bring the samples from the main cylinder of the main blade to the working fluid circulating in the system as close as possible, and to take a sample of the working fluid from the conditions of a difficult update.

Table 1. The results of laboratory studies of the working fluid.

| №  | Sample name                                | Total acid number, [mg] KOH for 1 g of oil according to GOST 5985 | Mass fraction of mechanical impurities, [%] according to GOST 6370 |
|----|-------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| 1  | Blade hydraulic cylinder (piston cavity)   | 0.58                                                          | 0.92                                                          |
As a result of the study of samples of the working fluid (Table 1), the value of acidity and the mass fraction of mechanical impurities were determined. In the samples there are serious deviations of the indicators, the values in the dozer dump are lower than in the main dump, this is due to the low workload of the dozer dump. Before sampling, the full working stroke of the hydraulic cylinders was performed, respectively, the difference in acidity values and the mass fraction of mechanical impurities indicates the difficulty of updating the working fluid. Studies have also been conducted to determine the types of mechanical impurities.

Table 2. Studies of the type and amount of metals in the samples

| № | Sample                               | Mechanical impurities |
|---|--------------------------------------|-----------------------|
|   |                                      | Lead, [mg / kg]       |
|   |                                      | Iron [mg / kg]        |
|   |                                      | Chromium [mg / kg]    |
| 1 | Hydraulic cylinder of the main dump  | 2,36                  |
|   |                                      | 9,27                  |
|   |                                      | 0,07                  |
| 2 | Cylinder of Dozer Blade              | 0,42                  |
|   |                                      | 8,8                   |
|   |                                      | -                     |

The study (table 2) revealed the presence of lead and iron in the samples, and chromium inclusions were also found in the hydraulic cylinder of the main blade. By the amount of impurities in the samples, it is also clear that updating the working fluid is difficult. It is especially worth noting the presence of chromium in the sample from the main blade and its absence in the hydraulic cylinder of the bulldozer blade, this gives us reason to assume that the degree of renewal of the working fluid in the hydraulic cylinder of the bulldozer blade is minimal.

It is worth noting that the process of replacing the working fluid in the hydraulic drive will not be a solution to the current problem. The process of replacing the working fluid consists in draining the working fluid from the hydraulic tank and then filling it with a new fluid. [7] In this case, the fluid from the pipeline practically does not drain, for units with difficulty updating the working fluid, this leads to a gradual accumulation of wear elements and, accordingly, to a decrease in the life of the hydraulic drive elements.

It is possible to solve the existing problem by introducing additional filters into the pipeline, introducing check valves in the hydraulic drive, or introducing an additional hydraulic distributor. In addition, a technique is needed to determine the nodes that have problems with the circulation of the working fluid.
Figure 2. filter plant
1- hydraulic cylinder, 2- check valve, 3- filter.

Figure 2 shows the configuration with the introduction of additional filters into the system (3) that clean the working fluid from contaminants. In addition, check valves (2) are also provided in the layout, one for each line. Check valves are embedded in the filter assembly in order to force the working fluid to circulate through the filter. When the rod extends, the working fluid flowing into the piston cavity of the hydraulic cylinder (1) from the distributor passes through the check valve, and in the case of fluid movement in the opposite direction, the check valve forcibly passes the working fluid through the filter of the rod cavity. The advantage of this arrangement is its simplicity, which allows to reduce the contamination of the working fluid without the need for high costs. A serious disadvantage of this arrangement is the remaining negative effect of the developed additives, since the filtering unit ensures the cleaning of the working fluid exclusively from the elements of mechanical wear. The introduction of the filter unit will significantly reduce the wear of the rubbing surfaces of the hydraulic cylinder, but will retain the negative impact of the additives developed in the remote nodes.
Figure 3. forced circulation unit
1- hydraulic cylinder, 2- block of reciprocating valves of the piston cavity,
3- block of check valves of the rod line.

The introduction of additional check valves (Figure 3) will improve the circulation of the working fluid in the nodes remote from the control valve, which will completely solve the problem of stagnation of the working fluid. The principle of operation is the introduction of two additional lines to the hydraulic tank (L2), which discharge the working fluid from the working cavities to the hydraulic tank, and the hydraulic cylinder (1) will receive liquid from the hydraulic tank through the existing highways (L1), which ultimately will ensure full circulation of the working tank. Fluid at remote sites. When the hydraulic cylinder rod extends, the working fluid flows from the L1 line of the piston cavity check valve block (2), and from the rod cavity, the working fluid flows through the rod valve check valve block (3) through the floor of the L2 line. The introduction of additional check valves will reduce the amount of mechanical impurities in the working fluid involved in the work, as well as provide an update of the additives in the working area. A significant disadvantage of this arrangement is the need to introduce additional pipelines.

For the development of methods for identifying nodes with difficult circulation of working fluid, it is necessary to conduct full-scale experiments to determine the degree of updating of the working fluid due to mixing. In identifying the nodes in which the circulation of the working fluid is difficult, it is necessary to introduce elements into the hydraulic actuator that ensure the forced circulation of the working fluid or its cleaning. The introduction of an additional unit for cleaning the working fluid will reduce the effect of the effect of obstructed circulation of the working fluid. It is necessary to note the high load on the filters in the remote nodes and ensure their proper maintenance. Introduction to the zones remote from the hydraulic distributor of the components ensuring the circulation of the working fluid, in the form of check valves or additional hydraulic distributors.

The introduction of additional methods for determining nodes subject to stagnation of working fluid and additional elements designed to make working fluid in remote sites meet the regulatory requirements
of purity, will increase the efficiency of methods for diagnosing hydraulic drive based on the analysis of working fluid, which will increase the service life of hydraulic drive construction and road machines and reduce the number unforeseen failures. This will ultimately lead to a decrease in machine downtime, an increase in its service life, a reduction in the cost of repairing the hydraulic drive elements, and an increase in efficiency.

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