SCIENTIFIC SUBSTANTIATION OF IMPROVED METHOD OF THE DIAGNOSIS OF HYDRAULIC DRIVES USED ON COMBINE HARVESTERS

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Abstract. *Maintaining of the combine harvesters in an efficient condition throughout the harvest season is an important task of technical service. The most important elements in the work of combine harvesters are their steering mechanisms, the performance of which must have a high degree of availability, especially of their hydraulic drives. The purpose of this study is to increase the operational reliability of the steering drives of the combine harvesters, based on the development of an improved method for diagnosing of their hydraulic drives. During the research, the methods of theoretical and experimental research were used, based on the theory of machine operation, hydraulics, as well as modern methods of experimental studies of hydraulic equipment. The data of the experimental studies were processed by statistical methods using a PC. Theoretically and experimentally, an improved method for diagnosing of the hydraulic drives has been developed with the aim to increase the technical readiness of combine harvesters and reduce the costs of their maintenance and repair. A new methodical approach and results of studies on the creation of a diagnostic system for the hydraulic drive of the combine harvester's power steering have been developed.*

KEYWORDS: *HYDRAULIC DRIVE, COMBINE HARVESTER, DIAGNOSINGS, VOLUMETRIC EFFICIENCY, RELIABILITY, DIAGNOSING TIME*

1. Introduction

As established by basic observations and studies [1], the optimal duration of harvesting of small grain crops, in which the loss of grain of grain crops should not exceed 2.5% of the harvested crop, should be no more than 7-10 days. Prolongation of the harvesting time can lead to significant losses, which can sometimes reach 20-30% of the crop yield [2]. Works on the preparation of feed and harvesting of root crops should also be carried out at the optimum time to prevent deterioration of the quality of harvested products and losses. One of the reasons for increasing the duration of harvesting is the insufficiently high reliability of combine harvesters, which leads to their downtime due to trouble shooting. The duration of combine harvesters downtime due to the maintenance and troubleshooting works reaches, in average, 0.5-0.6 hours per hour of net harvester work [3, 8,]. A significant part of the downtime is associated with the elimination of faults in the hydraulic drives of combine harvesters.

About 24% of failures, from the total number of failures on the combine harvesters, falls on hydraulic drives [4, 10, 11]. The reliability of the work of combine harvesters largely depends on the level of technical service [5, 6].

2. Results and Discussion

As a main aim of the study was to increase the technical reliability of combine harvesters s and reduce the costs of their maintenance and repair.

Increasing the reliability of the hydraulic drives of combine harvesters is affected by timely detection at early stages of development and troubleshooting. This is achieved by creating and implementing of a system for the technical diagnosis of hydraulic drives, which ensures the interaction of the facility and diagnostic tools with the solution of the following issues: the determination of the type and purpose of the diagnostic systems; analysis of physical processes that take place in the object of diagnosis in order to establish the mechanisms of occurrence and signs of manifestations of injuries and defects; establishment of a list and normative values of diagnostic parameters that characterize the technical station of hydroelectric units; development of diagnostic tools and algorithms for troubleshooting. Such methodical approach was implemented when creating a diagnostic system for the hydraulic drive of the combine harvesters steering. The most expedient, at this stage, for hydraulic steering is the use of a functional type of diagnosis with the determination of both the general technical state and locally individual units using a portable set of mechanical external diagnostic tools.

The main purpose of the diagnostic system is to search for malfunctions and determine the technical condition of hydraulic units and predict the period of their further operation. An analysis of the physical processes that occur during the operation of the hydraulic drive is carried out by using the diagnostic model (Fig. 1).

To do this, a specific hydraulic power steering is conventionally divided into structural units, which can be as follows: a working fluid tank (*T*); power supply pump (*CP*); pump-dozer (*DP*); hydraulic cylinders (C_H); controlled wheels (*KK*). The structural-functional model is built for the following modes of operation of the steering: the movement of the combine harvester in straight direction or curvilinear with a fixed turning radius; rotation of controlled wheels at different speeds with a movable and immovable combine harvester; turning of the combine harvester with the pump running and in idle working regime.

Each block of the structural-functional model is characterized by the action of external and internal input and initial parameters. Each of the parameters presented in the diagnostic model for a particular operating mode of the hydraulic drive meets the quantitative value according to the technical requirements for the manufacture of hydraulic units and their components. Changing these parameters during the operation of the hydraulic drive leads to a disruption in the working process, which is characterized by different types of faults.

Experimental studies have been carried out to establish the nature of the changes in the structural parameters of hydraulic units and their effect on the operational performance of the steering of a combine harvester. The sets of hydraulic units of the steering with different degrees of wear were selected. With the complete sets of hydraulic units, tests were carried out according to the parameters with regard to the technical requirements for manufacturing. After the tests, the hydraulic units were dismantled and a there was done the determination of the change in the structural parameters (dimensions) of the surfaces of the parts, which were worked out during operation. The results of the measurements (micrometer) were processed according to existing methods.

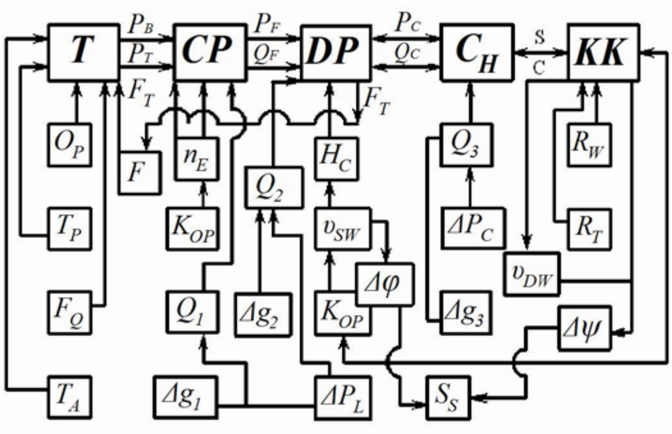

***Fig. 1** – Diagnostic model of the hydraulic drive of the combine harvester power steering: T – tank; CP – charging pump; DP – dosing pump; C_H – hydraulic cylinders; KK – steering wheels; T_A – air temperature; T_F – working fluid temperature; O_P – level of the working fluid in the tank; FQ – quality of working fluid; F – filter; F_T – draining the working fluid in the tank; P_B, P_T – pressure or vacuum in the suction line; Q_F, P_F – feed and pressure of the working fluid at the output of the feed pump; n_E – engine crankshaft speed; K_{OP} – operator command; Q_1, Q_2, Q_3 – losses of the working fluid in the make-up pump, dosing pump and hydraulic cylinders; Δg_1, Δg_2, Δg_3 – gaps in the connections of the parts of the make-up pump, the metering pump and the hydraulic cylinders; ΔP_L, ΔP_C – the pressure drop of the working fluid in the feed-back pump clearances and the hydraulic cylinders; H_C – pump-motor control; υ_{SW} – steering wheel turning speed; $\Delta\varphi$ – turning angle increase of the steering wheel; S – steering sensitivity; $\Delta\psi$ – increase of the turning angle of the steering wheels; Q_C, P_C – feed and pressure of hydraulic fluid in the cavities of hydraulic cylinders; S, C – displacement and force of the rods of hydraulic cylinders; υ_{DW} – turning speed of the driving wheels; R_W – external resistance of the wheels return; R_T – frictional resistance in mechanisms.*

Figure 2 shows the dependence of the volume efficiency (η) of the NSh-10 pump on the total gap (δ_g) in the joints of the housing – the gear teeth, the bearing – the end of the gear teeth, the bearing – the pinion shaft, the bearing housing and the operating time of the combine harvester. The wear of the surfaces of the parts leads to an increase in the clearances in the joints, which causes an increase in the loss of working fluid in the pump.

The volumetric efficiency of the NSh-10 pump was determined as a result of dividing the actual supply of the working fluid by the theoretical feed at the appropriate speed of the drive shaft, the nominal pressure and temperature. The wearing of the surfaces of the parts leads to an increase in the gaps in the matings, which also causes a decrease the value of the volumetric efficiency of the pump.

According to the data of experimental studies, the loss of working fluid in the conjugation "body-spool" of the dispenser dispenser makes up about 90% of the total loss of working fluid in the metering pump and can reach the value 18 $l \cdot min^{-1}$.

Loss of working fluid in the couplement of the flow amplifier components, preliminary and shut-off valves, power cylinders change during operation in a small range (0.05-0.06 $l .min^{-1}$) and during maintenance can be reduced to almost nominal values by performing adjusting and cleaning operations, as well as by replacing the seal.

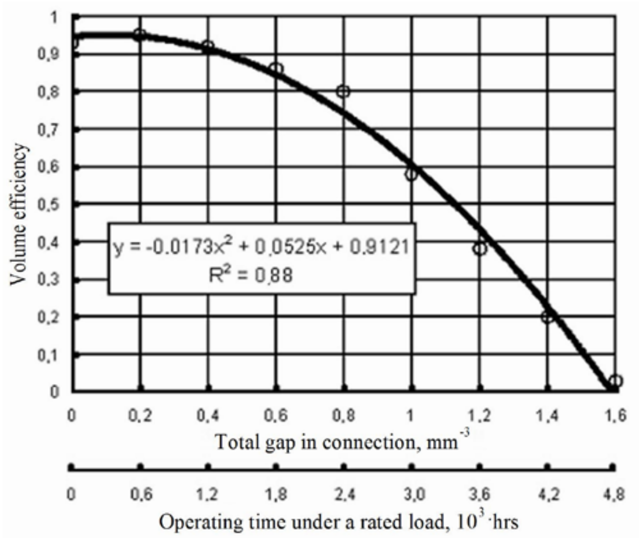

***Fig. 2** – Dependence of the volume efficiency (η) of the NSh-10 pump on the total gap (δ_g) in the joints of the housing – the gear teeth, the bearing – the end of the gear teeth, the bearing – the pinion shaft, the bearing housing and the operating time of the combine: y(x) – regression equation; R^2 – the probability of approximation; ΔP = 10 MPa – decrease of the pressure of the working fluid in the joints*

To determine the effect of changes in structural parameters on the main performance indicators of the operability of steering control of combine harvesters, which are regulated by the relevant standards [6], the experimental studies were carried out.

Complete sets of hydrounits of the power steering of the combine harvesters with different degree of wear of the surfaces of the parts were installed on the experimental installation, on which such parameters were created and controlled:

- frequency of the drive shaft of the gear pump; Feeding of the supply pump and the metering pump;
- pressure and temperature of the working fluid;
- steering wheel speed;
- the duration of the complete displacement of the pistons of the hydraulic cylinders, which corresponds to the complete rotation of the steerable wheels from one extreme position to the other;
- speed of the steering wheel slip;
- speed of displacement of pistons of hydraulic cylinders;
- load on the rods of hydraulic cylinders;
- loss of working fluid in hydraulic units and their interfacing.

Tests were carried out on the working fluid, which is provided by the manufacturer for a particular combine harvester. The load regimes and the temperature of the working fluid were created within the limits prescribed by the normative documentation for hydroelectric generators and combine harvesters. During the experimental studies, the evaluation of the initial diagnostic parameters that characterize the overall technical condition of the hydraulic power steering and the hydraulic units and their components was given.

In determining the appropriateness of using a particular diagnostic parameter, the following criteria were used:

- the reliability of technical diagnosis;
- time-consuming (duration) of diagnosis;
- fitness of the object for diagnosis;
- universality and cost of technical diagnostic tools;
- completeness and depth of diagnosis.

Based on the results of the study, a list and normative values of diagnostic parameters (nominal, permissible, limiting) were determined.

The nominal values of the diagnostic parameters correspond to the nominal values of the technical condition parameters of the new hydraulic units in accordance with the technical requirements of the manufacturer. Limit values of diagnostic parameters meet the technical condition of hydraulic units, in which further operation of combine harvesters is impossible based on the requirements of traffic safety and cost-effectiveness.

The permissible values of the diagnostic parameters were determined according to the existing methods [7] proceeding from the fact that they meet the technical condition of the hydraulic units in which this unit has the possibility to operate during the determined period of time without fail until the next diagnosis:

$$P_A = P_N - \frac{P_L - P_N}{\left(1 + \frac{T_2}{T_1}\right)^{\alpha}},$$

where P_A – allowable value of the deviation of the diagnostic parameter; P_N – the maximum (nominal) value of the diagnostic parameter for the new unit; P_L – limit value of the diagnostic parameter; T_2 – normative value of the before-repair life of the unit; T_1 – the normative value of the frequency of diagnosing; α – indicator of the unit wearing dynamics.

To measure justified diagnostic parameters, the sets of means for their use have been developed [9].

Troubleshooting is carried out according to the developed algorithms. A set of mutually agreed rules, methods and means of express, operational and periodic diagnosis of hydraulic drives of combine harvesters, the effectiveness of which was confirmed by laboratory and production tests.

3. Conclusions

1. The application of the developed system of technical diagnostics of hydraulic drives of the combine harvesters steering control ensures that the readiness of the hydraulic turbo units is adjusted to 0.85-0.90, and increases the use of their resource by 20-25%.

2. The duration of express diagnosis of the hydraulic power steering has the average value of about 5 minutes, and a full diagnosis using external technical diagnostics is about 30 minutes.

3. The credibility of the technical diagnosis of the hydraulic steering gear for a given depth of fault location is in the range of 90-95%.

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