Technical condition diagnostics of potato combine harvester

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Abstract. The technical condition of the combine harvester is one of the critical factors affecting the performance of mechanized potato harvesting. In order to maintain the required level of reliability and durability of farming machinery used for potato harvesting, the authors propose to perform maintenance checks of the mechanical drive on the lifting section of the harvester while turning the drive shaft in two modes: with free and fixed auger. This approach uncovers new dynamic maintenance parameters, which can help detect malfunctions in the safety clutches and working components of the potato harvester, determine when the safety clutches operate, and evaluate the loads acting on the transmission and related parts of the mechanical drive. The study was carried out for three harvesting seasons in the farms of the Irkutsk region using the potato combine harvester KPK-2-01+ MTZ-80. The results can be applied when setting up and adjusting potato harvesters, and when evaluating the technical condition of potato harvesting units with the required configuration.

1. Introduction
Mechanized potato harvesting is a labour-intensive agricultural process that includes processing steps such as removing tops and plant residue, digging up tubers, soil-tuber separation, loading potatoes into vehicles and transporting them from the field, loading tubers into storage and unloading them into the receiving hopper at the sorting station. Factors such as the technology used, the soil and climatic conditions, selection of personnel, coordinated work of harvesting machines (tractors, combine harvesters and dump trucks), and their technical condition and reliability determine the quality, care and speed (within the established agro-technical terms) at which the potato will be harvested [1-4].

The majority of studies analysing operation of potato harvesting processes focus mainly on the technical condition of farming machines used for harvesting [5-8]. Recently, a large number of measuring devices designed to assess the technical condition of potato harvesting equipment have been developed, which can determine deviations between the values of a number of diagnostic parameters and their rated values [9-14]. However, they were not widely used due to their high cost and the fact that they are impossible to use in the field.

In this regard, the objective of this study is to identify diagnostic parameters based on the simulation diagnostics of the mechanical drive of the potato harvesters.

2. Materials and methods
Trailed potato harvester designs widely utilize mechanical drives that propose simplicity, high efficiency, affordable maintainability, low cost and high reliability during operation. Therefore, the technical condition of the potato combine harvester can be diagnosed by evaluating the mechanical drive
used in its working components. The mechanical drive on the lifting section of two-row potato harvester KPK-2-01 was studied.

Figure 1 shows a diagram with the units of the main power train and locations of the safety clutches on the working components of the combine harvester, where the numbers denote the transmission units (1, 3 is the drive shaft; 2 is the coupling; 4, 5, 6, 8 is the gearbox; 7 is the chain gear), the letters denote the safety clutches and Roman numerals denote places where they are secured.

The backlash in the power train, total backlash in the transmission unit, actuation force of the safety clutch and torque of the harvester drive shaft were used as dynamic diagnostic parameters of the mechanical drive. Experiments showed that the resistance moment on the drive shaft changes discontinuously in-creasing up to a certain value $M_{\text{sum}}$, which coincides with the value of the friction force between the components of the drive. The further change in its value creates a variable disturbance moment $M_{\text{var}}$. In order to de-termine the behaviour of the torque, experiments were carried out in two modes: with free turning of the drive shaft and with fixed sorting table of the combine harvester figure 2.

Free turning of the drive shaft showed an increase in the torque up to $M_{\text{prok}} = 90...95$ Nm, and a decrease after that. In the power train, every backlash was selected where the torque reached maximum. According to figure 2, the discrepancy between the moments of action of the main safety clutch and the maximum torque moment was $\Delta \phi \approx 40-50^\circ$, which is due to the fact that this is the time when backlash adjustment takes place in the kinematic chain, and the total backlash in this case was $\phi_{\text{sum}} \approx 480^\circ$. The moment of action of the main safety clutch figure 1, c is the difference between the maximum moment and the torque moment on the drive shaft $M_{\text{srab}}=290$ Nm, which is 10 % lower than the rated moment. It should be noted that the values of three dynamic parameters were obtained in a simple manner, by only turning the drive shaft in two modes.
Figure 2. Dynamics of changes in the values of the drive shaft torque of the combine.

3. Research results and discussion

Using this approach, the experiments modelled the malfunction due to the backlash in the key joint of the semi-permanent coupling 2 figure 1. Figure 2 shows this as section a. Notably, the malfunction does not manifest itself while simply turning the drive shaft of the harvester, but only a surge of the torque leads to a dynamic shock in the coupling.

Figure 3 shows the torque history during the action of the main safety clutch, when the drive is blocked in the detachment IV figure 1, in which case the main hopper and auger disks rotate. The moment of torque resistance on this section of the chain was $M_{prok} = 25 \text{ Nm}$.

Figure 3. Dynamics of changes of the moment when the safety clutch is triggered.

Stopping the drive in the section IV figure 1 created the moment of action $M_{srab} = 75 \text{ Nm}$ on the clutch. The second curve shown in the figure describes the change in the moment of action on the main clutch. The total backlash on the segment $O-IV$ of the chain was $\phi_{bok} = 190^\circ$.

Analysis of the plots in figures 2 and 3 shows that obtaining more reliable information when finding the values of the moment of action on the safety clutch requires us to determine the section of the kinematic chain, where the drive should be stopped.

Another example figure 4 shows history of the moment of action on the clutch of the auger disks $a$, measured when turning the drive of all the components of the harvester as the auger is stopped in section II figure 1.
We obtain $M_{srab} = 90$ Nm by turning the mechanical drive of all the harvester components and determining the moment of action on the clutch as the difference between the maximum moment as shown on the plot and the actual value of the torque moment. If we measure the value of the moment of action on the clutch as the difference between the maximum turning moment and the torque moment on the lifting section $M_{srab} = 115 - 25 = 90$ Nm, then we will find that in both cases the values are 75% of the rated value. The backlash in the drive before the disk couplings of the auger was similar in both cases and was equal to $\varphi \approx 240^\circ$. The turning force on the remaining working components of the harvester apart from the lifting section was equal to $M$ and was measured as the difference between the maximum values of the moments.

4. Conclusion
Performing the maintenance check of the potato combine harvester by evaluating the mechanical drive of the harvester in different turning modes of the drive shaft allowed us to determine various diagnostic parameters, such as the moment of turning resistance, moment of action on the drive clutches, and the drive backlash. All these parameters indicate the wear of parts, increased backlash in their couplings and improper adjustment. The approaches used (stopping the output shaft of the clutch, turning the shaft with uncoupling of individual sections of the kinematic chain) do not require disassembly of the working components and protect components of the power train and related parts of the drive. The results may be used for fine adjustment of the safety clutches on the drive, determining the quality of repairs of individual sections of the kinematic chain and evaluating the technical condition of the potato combine harvester as a whole.

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