UDC 629.083
DOI: 10.15587/2706-5448.2020.214172

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DEVELOPMENT OF A SYSTEM FOR DIAGNOSING BEARING ASSEMBLIES WITH POLYMER PARTS DURING OPERATION

The object of research is the process of monitoring the limiting wear of polymer-composite bushings of the bearing unit of the parallelogram mechanism of seeding machines. This process is clearly manifested in determining the good condition of the moving joints of machines operating in severe operating conditions. The studies performed are based on the principle of breaking the active link. The diagnostics is based on this principle, which makes it possible to assert with sufficient accuracy about the failure of the control link of the mates of parts. The main hypothesis of the study is that by developing a diagnostic system based on the control of composite bushings, it is possible to determine the boundaries of the normal functioning of the sowing sections as a whole. The solution of this issue without intervention in the design of the sowing section itself is impossible. Since the material of the sleeve is a polymer composite, which has sufficient resistance not to pass an electric current, conditions are created for the implementation of the proposed diagnostic system. In this work, a regression model is built to control and identify changes in the lateral backlash from the operating time of the seeding complex. By analyzing the data obtained, it is possible to establish the relationship between the diagnostic parameter, namely, the fixation of the rupture of the active link passing near the working surface of the composite sleeve. The main limitations in the development of this diagnostic system are the boundaries of the control gaps in the mates, as well as the presence of dielectric materials for the control parts. In the case of a significant occurrence of an active rupture link or an incorrect selection of its required diameter, then this diagnostic method may work inappropriately and the diagnostic system becomes ineffective. The work reflects the timeliness and rationality of the developed diagnostic system. On the basis of such a diagnostic system, it is possible to create an automated diagnostic complex for monitoring the state of the parallelogram mechanisms of the seeding complex as a whole.

Keywords: *limiting clearance, bearing unit, side backlash, parallelogram mechanism, polymer sleeve, sowing section.*

Received date: 28.04.2020
Accepted date: 04.06.2020
Published date: 31.10.2020

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1. Introduction

The implementation of a system for diagnosing bearing assemblies is an important scientific and technical problem, which makes it possible to assess their technical condition during operation [1–3]. The implementation of these systems in machines operated in severe operating conditions also creates optimal conditions for performing technical service operations of control units and technical systems [4–6]. Timely replacement of parts of movable joints can significantly reduce technological costs when using agricultural machines. Thus, in the event of a malfunction of the Parallelogram mechanisms of seeding complexes, the possible loss of 4–19 % of profit in terms of yield in agricultural enterprises. To increase the reliability of the Parallelogram mechanisms of seeding complexes, it is proposed to use polymer-composite bushings. The introduction of these parts also requires their timely replacement, since at certain gaps in the movable joints, the processes of destruction to wear of the bushing material intensively proceed. Therefore, the development of a bearing assembly diagnostic system is a very urgent scientific and technical task that requires a solution.

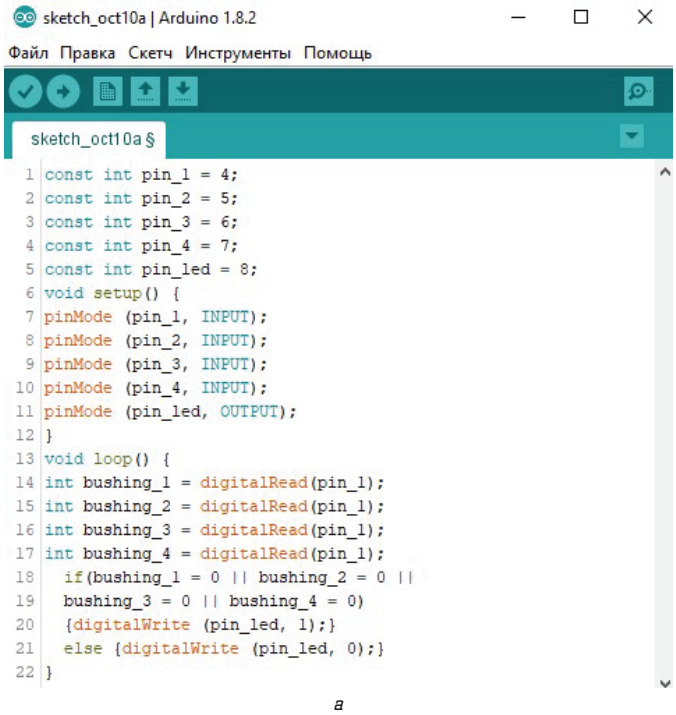
The object of research is the process of monitoring the limit wear of polymer-composite bushings of the bearing unit of the parallelogram mechanism of seeding complexes. *The aim of research* is to create a system for diagnostics of bearing assemblies with parts of polymer materials of sowing complexes during their operation.

2. Methods of research

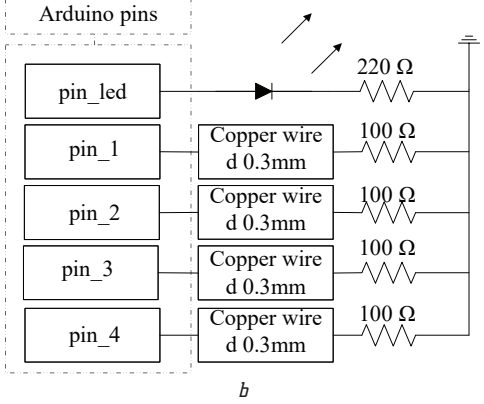
To develop a system for diagnosing polymer-composite bearings, the principle of breaking the active link is used. This principle is characterized by the fact that the limiting amount of wear is controlled by breaking the electrical circuit, which lies at the required depth in the material of the part [7–9]. The polymer composite has electrical resistance, which allows the use of an electrical wire with a minimum diameter. The limiting clearance, which is formed during wear in the bearing unit of the parallelogram mechanism of seeding machines, is 0.6–0.7 mm. This is determined during the service of Turbosem II 19-60 (Ukraine) by measuring spent polymer bushings using a SHAHE 5401-400 digital micrometer (China) and then comparing their dimensions with new bushings of movable joints. A sowing

complex with sowing sections that have worn bushings can't provide the required accuracy of sowing seeds into the soil in the field. Wear in the bushings within 0.03–0.07 mm creates a backlash of 4–5 cm from the axis of the seeding section to the left and right sides. Review and control can and should be carried out every 96 hours of operating time of the Turbosem II 19-60 sowing complex. Polymer composite bushings are made by injection molding from OHA-6-30 material. Copper wire with a diameter of 0.3 mm was laid in a spiral groove with a turn pitch of 8 mm on a composite sleeve, which makes it possible to control the wear of the working surface of the sleeve. The turn pitch should be no more than 30 % of the length of the controlled working surface [10]. On both end surfaces of the bushings, a sliding brush assembly is mounted, to which a copper wire with a diameter of 0.3 mm is connected.

Fig. 1 shows the functional content of the diagnostic system. The system includes a code and a circuit diagram of the connection. The electronic part is implemented on an Arduino Mini board with an ATmega 328 microcontroller (China) with 14 digital inputs/outputs, fully sufficient for one Turbosem AI 19-60 seed section.



a



b

Fig. 1. The functional content of the diagnostic system: *a* – program code; *b* – electrical circuit diagram

This system is triggered when any wire of the polymer sleeve experiences wear, which breaks the electrical circuit. In this case, the signal LED for the section under test will light up.

3. Research results and discussion

During the operation of the Turbosem II 19-60 seeding complex with sowing sections, they have bearing units with polymer composites in their set, the resource was observed to be increased by almost 1.8 times more compared to the basic steel units. It is shown that composite bearings also make it possible to develop and implement simplified diagnostic systems. Under these conditions, the functional meaning of the diagnostic system for 5 sowing sections has been developed. This reduces the number of service inspections until the appearance of extreme wear in any bearing unit of the parallel mechanism. Data collection during operation is carried out without deviating from the regulated maintenance schedule for this seeding complex. The minimum backlash in the parallelogram mechanism, determined by organoleptic methods, is recorded in the service log as a completely absent malfunction.

It is revealed that polymer-composite bearings have good resource indicators: up to 17250 hectares of the total operating time of the complex, some significant changes in the backlash of the sowing sections are not noticed. Fig. 2 shows the dependences of the side backlash change on the operating time for the Turbosem II 19-60 seeding complex with polymer bearings.

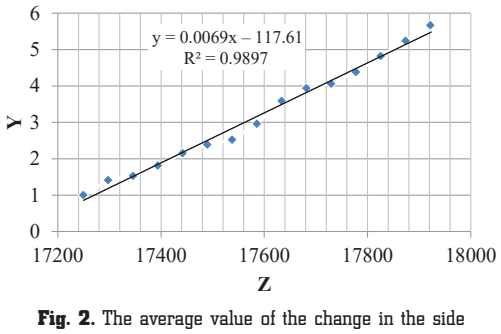


Fig. 2. The average value of the change in the side backlash of the seeding sections from the operating time of the seeding complex: *Y* – backlash from the axis of the seeding section, cm; *Z* – operating time of the sowing complex, ha

Fig. 2 indicates that the sowing complex with polymer composites works satisfactorily up to 17730 ha. Limit lift values are not recorded. After 17730 hectares, the backlashes enter the zone of maximum wear. Under such conditions, it is necessary to schedule service operations more often or replace the polymer sleeves.

During the scheduled maintenance, let's also record the ignition of the LED lamp on the investigated sowing sections. Table 1 shows the data on signaling the limit wear of polymer composite bearings. No diagnostic signal fires occurred in the range of up to 17700 ha.

Analyzing the data in the Table 1, it can be argued that the limiting wear of polymer composites began from 17730 hectares, as evidenced by the fixation of movable units with polymer parts by the diagnostic system. And in the interval of operating time of 17874–17922 hectares, all research diagnostic systems

 ISSN 2664-9969

worked. Under such conditions, it can be argued that the existing system can function and, in turn, display data on the malfunction within acceptable limits.

Table 1

Side backlash of the parallelogram mechanism

Operating time, ha	17634	17682	17730	17778	17826	17874	17922
Number of signal diodes	0	0	1	1	2	4	5

It should be noted that the formation of polymer bushings with a diagnostic rupture link is an effective opportunity to solve the issue of monitoring the technical condition of bearing assemblies.

4. Conclusions

The paper shows that the development of a diagnostic system for bearing assemblies with polymer parts during operation, based on the principle of rupture of the active link, reduces the cost of monitoring these assemblies. The results of the technical condition according to the value of the backlash deviation show that the sowing sections should be repaired when the operating time is 17778–17922 hectares, and the diagnostic system worked on 17730 hectares of operating time. Therefore, using this system and its principles in the future, it is possible to develop an automated diagnostic system for sowing sections with bearing assemblies made of polymer parts.

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