Study of the wear resistance of hardened harrows of agricultural machines

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Abstract. The conducted research is devoted to the analysis of the wear resistance of materials used in reinforcing coatings of working bodies of agricultural machines subjected to friction under abrasive action in soil conditions. The aim of the study was to determine the degree of wear of the hardened teeth of the disc under the load of their impact on the soil in real operating conditions. The disk of a toothed harrow, which is a hardened working body of agricultural machinery, was used as an object of research. The individual teeth of this disc were the test samples. To increase the wear resistance of the teeth, a variety of reinforcing coatings were applied. The results of the study made it possible to comparatively evaluate the effectiveness of various reinforcing coatings and identify their effect on the wear resistance of the teeth of the disc. This study provides important data for further improvement of materials and technologies in agricultural engineering in order to increase the durability and efficiency of working bodies.

1 Introduction

Increasing the reliability, service life and wear resistance of the working bodies of agricultural machinery and equipment, especially the working bodies (RO) of tillage machines and aggregates operating under conditions of intense abrasive and impact-abrasive wear, is an urgent problem in agricultural machinery and practical agriculture [1-2].

The determination of wear mechanisms plays an important role in wear monitoring, as this information is important for maintenance periods [3-5]. Existing control methods have limited capabilities to assess the degree of wear. For example, the vibration method and the acoustic emission (AE) method are primarily designed to detect and diagnose local damage, rather than to monitor integral wear [5-7]. Wear product analysis (WDA) is a more efficient technology compared to the acoustic emission method and has demonstrated extensive possibilities for assessing the wear mechanism based on such characteristics of wear products as their size, quantity, morphology and color [8-10]. However, these signs of wear products

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are insufficient to reconstruct the surface of the gear teeth, and the accuracy of this method may also be affected by deformation of wear products, accumulation of foreign particles, contamination, etc. [10-12].

An analysis of the working conditions, maintenance and repair of modern agricultural machinery shows that during its operation, the greatest losses of time, resources and materials are observed when replacing individual suddenly failed parts (aggregates, individual parts) and worn-out RO, which many researchers even suggest to be attributed to consumables.

First of all, this is due to the low efficiency and service life of RO, which in agricultural machinery, as a rule, are made from an affordable range of carbon, structural and low-alloy steels with low cost and widespread in the industry: 35L, 45, 65G, 50HGA, etc. To improve performance and increase the service life, hardness and wear resistance, these parts are subjected to heat treatment and other hardening methods. Nevertheless, the paws of cultivators, drill bits, plowshares, husker discs, etc. such parts are among the most rapidly wearing parts. Recently, there has been a clear trend to replace these steels (especially in the manufacture of imported RO machines) with new structural materials, in particular boron steel 30MnB5, but their cost is still several times higher than RO made from domestic materials.

In this regard, researchers are constantly searching for the creation of new materials and their assessment of the ability to withstand abrasive and impact-abrasive wear, regardless of the variety of soils. Depending on the methods of applying wear-resistant coatings and their physical and mechanical condition.

To assess the impact of the abrasive environment on the working bodies of agricultural machinery, a significant number of laboratory methods, machines, devices, soil channels have been created and are currently being offered, both in the Russian Federation and abroad. However, previous studies have shown that adequate wear conditions of the working bodies of tillage machines can be reproduced. It is practically impossible and has no economic feasibility.

Field tests provide more reliable information about the wear resistance of the working bodies of agricultural machinery and allow you to determine the wear figure and the nature of wear of individual structural elements of the tillage body of an agricultural machine and decide which material and method to strengthen the wear part of the part.

To strengthen the cutting edge of the parts under study, modern technologies widely use methods of applying various hard, wear-resistant and functional coatings: flame, arc, laser and plasma surfacing, induction (HDPE) surfacing, the creation of bimetallic elements on the cutting edge by cladding, etc. [9-10].

As a result of this process, a layer with very good properties can be obtained, such as high microhardness, good wear resistance and corrosion resistance [11-14]. Due to the needle-like microstructure, the borated layer is characterized by good adhesion to the steel substrate. However, despite these numerous advantages, borated layers are quite fragile. This disadvantage can manifest itself in the form of chips and peeling from the substrate [11]. At the same time, there are many methods to increase the strength and stability of such layers [15-18]. One of them is heating by high frequency currents (HDTV) during the formation of a diffusion boron layer [14, 15]. This results in a layer with a modified microstructure and new properties such as high hardness, strength, wear resistance and corrosion resistance [19]. However, at present, the vast majority of known methods of borating steel (including furnace, gas and electrolytic) are characterized by a long lead time, a high degree of labor, a low degree of automation and limited integration into technological schemes of modern production. A significant intensification of boration occurs during high-speed HDPE heating of the steel surface under a layer of a special borated charge [20-22].

The aim of the work is to study the degree of influence of soil types on the study and investigation of various parameters of materials applied to the surface of the hardened part in various ways.

2 Materials and methods

The objects of the study were toothed discs for the BDT-7 harrow, which are subjected to various types of hardening.

The essence of the research carried out consists in coating the test samples, installing them on the working body of agricultural equipment, monitoring wear during operation in an abrasive environment and comparing wear values. The disk of a toothed harrow is used as a hardened working organ of agricultural equipment, and their teeth are used as test samples. Various reinforcing coatings are applied to the teeth of the disc, while the natural environment of various types of soils is used as an abrasive medium, and wear values are compared between the teeth of one disc.

The object of the study was a toothed disk, the teeth of which were strengthened with various materials and methods (Figure 1).

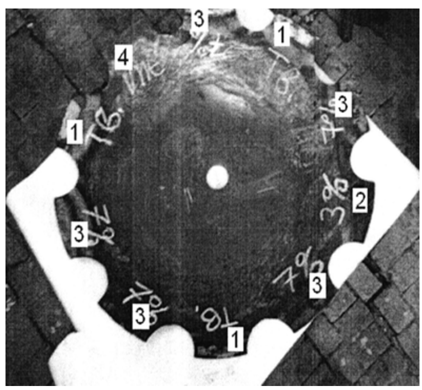

Fig. 1. A toothed disk, the teeth of which are reinforced with various materials and methods: 1 - HDPE surfacing, PG-US25-85% P-0.66-15%; 2 - HDPE surfacing + borer. composition 3%; 3 - HDPE surfacing + borer. composition 7%; 4 - Electric spark hardening, VK8 alloy.

Each tooth of the disc is reinforced with a sample material, and subsequently another coating is possible, both in chemical composition and in another way of applying a wear-resistant material.

Electric spark hardening was carried out on the BIG-5 installation, sintered with VK8 alloy.

The charge for boration consisted of: (boron carbide B4 C-80% + flux P-0.66-20%).

The surfacing charge contained 85% high-alloyed chromium cast iron grade PG-US25 and flux grade P-0.66.

The surfacing charge with a borating composition of 3% and 7% was mixed in a biconus mixer, and weighing was carried out on scales of the VLG-MG4.01 brand.

The tests were carried out on a hardened batch of 6 discs and on two types of soils: southern chernozem soil with an abrasive particle content of up to 65% and ordinary chernozem (up to 80% of abrasive particles).

The conditions of the experiments were as follows: soil volume humidity of 17-18%, at a depth of 50-100 mm.

During the implementation of the experiment, the linear dimensions of tooth wear were determined.

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Linear dimensions were measured with a caliper ShTs-2,150-500 and when installing a toothed harrow in a special device, Figure 2.

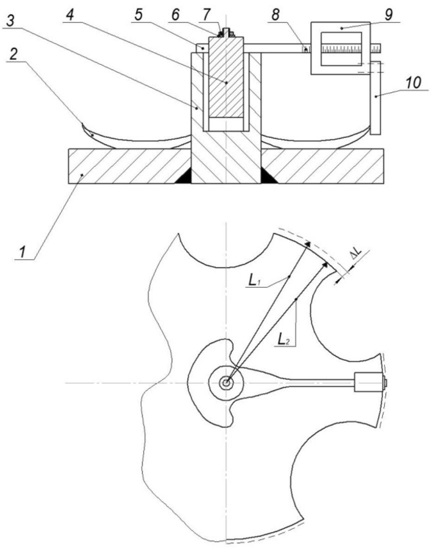

Fig. 2. Device for measuring harrow disc tooth wear: 1 - plate; 2 - harrow disc; 3 - cup; 4 - axis; 5 - measuring stick; 6 - washer; 7 - nut; 8 - scale; 9 - slider; 10 - fixing bar; L1 - measurement before disc wear; L2 - measurement after wear of the disc in the soil; ΔL is the wear value of the harrow tooth.

The measurement error was + 0.1 mm.

The assessment of the wear resistance of the reinforcing material and the method of its application was determined by the magnitude of linear wear.

3 Results and discussion

A disc harrow BDT-7 was used to assess the wear of the working organs.

The toothed disk was surfaced on an inverter at a frequency of 60 kHz, the heating and melting time ranged from 50 to 65 seconds.

Studies have shown that the wear of the surface of the teeth of the disc (Figure 3) has changed with all types of hardening (thickness by 0.3-0.6 mm).

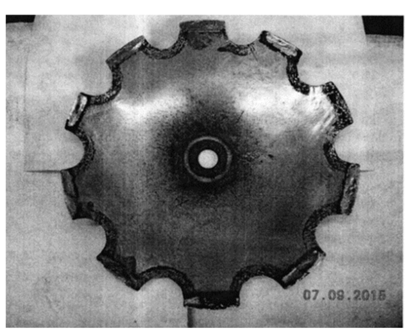

Fig. 3. Characteristic wear of the teeth of the BDT-7 disc.

The wear of the discs leads to a decrease in their diameter, which in turn leads to uneven peeling depth and a decrease in the quality of tillage. There are significant deviations from the set processing depth, reaching 90% compared to the permissible 10%.

In the course of the conducted research, it was revealed that the wear resistance of materials applied to working bodies is influenced by various factors, such as the properties of the hardened material, the method of its application, the speed of movement in an abrasive medium, as well as the mechanical composition of the soil. The most common criterion for assessing the abrasive wear of soils is the content of particles of "physical" sand in them, the size of which exceeds 0.01 mm. According to this criterion, soils are classified into three groups.

The first group of soils is characterized by low wear capacity and up to 80% content of particles of "physical" sand. The second group includes sandy loam and sandy soils with moderate abrasive wear, where the content of "physical" sand ranges from 80% to 95%, and rocky inclusions are insignificant. The third group includes soils with a "physical" sand content from 95% to 100%, characterized by a significant number of stones and a high level of abrasive wear [13].

Comparing Tables No.1 and No.2, there is a general trend of the influence of the content of abrasive particles on the wear of the hardened coating in the soil, regardless of its chemical composition and the method of hardening the surface of the tooth disc. Linear wear occurs in all hardened teeth, regardless of the method of hardening and the material to be hardened during electric spark hardening of the working bodies in the second case, the wear of the blade surface is less (3.0 mm) than in the first (4 mm).

This is explained by the fact that during electric spark hardening, the materials applied to the part being strengthened, as a rule, do not have transition strips, which are especially clearly observed when surfacing alloys that differ significantly from each other and the crystal lattices of both materials are completed to the principle of "compliance" forming a non-detachable joint. In case of impact-abrasive wear of the electric spark coating, in case of violation of its continuity, wear is avalanche-like, despite the fact that wear-resistant components such as tungsten are used in electric spark hardening.

Differences in wear resistance from the type of soil are also observed in the chemical composition of the reinforcing coatings.

Table 1. Wear of materials of reinforced coatings of working bodies of agricultural machinery with a content of abrasive particles in the soil up to 65 %.

Hardening method	**Option number**	**Harrow tooth length before test L_1, mm**	**Harrow tooth length before test L_2, mm**	**Harrow tooth wear value, ΔL, mm**
HDPE surfacing, PG-US25-85% P-0.66-15%	1	328	324.5	3.5
HDPE surfacing + borer. composition 3%	2	328	325.0	3.0
HDPE surfacing + borer. composition 7%	3	328	325.6	2.4
Electric spark hardening, VK8 alloy	4	328	324.0	4.0

Table 2. Wear of materials of reinforced coatings of working bodies of agricultural machinery with a content of abrasive particles in the soil up to 80 %.

Hardening method	Option number	Harrow tooth length before test L_1, mm	Harrow tooth length before test L_2, mm	Harrow tooth wear value, ΔL, mm
HDPE surfacing, PG-US25-85% P-0.66-15%	1	328	323.5	4.5
HDPE surfacing + borer. composition 3%	2	328	324.0	4.0
HDPE surfacing + borer. composition 7%	3	328	324.5	3.5
Electric spark hardening, VK8 alloy	4	328	325.0	3.0

4 Conclusion

A study of the wear of the working bodies of the BDT-7 toothed disc harrow, in the field, hardened in various ways, in various soils showed that with the content of abrasive components from 65% to 80%, the wear of the working bodies of agricultural machinery increases by 15-30%, and with an increase in the content of boron carbide in the surfacing charge from 3% to 7% the wear resistance of the hardened surface increases to 37% compared to the original one. The general tendency of the influence of the content of abrasive particles on the wear of the hardened coating in the soil, regardless of its chemical composition and the method of hardening the surface of the tooth disc, has been established. It is established that in case of shock-abrasive wear of the electric spark coating in case of violation of its continuity, wear is avalanche character.

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