Zonal-distributed structuring of working bodies of the agricultural sector

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Abstract. Increasing the wear resistance of working bodies of tillage machines is an urgent problem of the agricultural sector. During the operation of tillage machines, their working bodies, including cutting blades, are subjected to dynamic loads, abrasive and chemical effects of the external environment, which provokes their wear. A promising direction for increasing the wear resistance of chisel bit cutting blades is to manufacture them from gray cast iron, which has the ability to bleach, i.e. it can form a very hard and wear-resistant cementite eutectic (ledeburite) along with graphite eutectic. The results of comparative tests for wear of medium-carbon and high-carbon steels after thermal hardening and a sample of gray cast iron SHC 30 are presented. The optimal method of strengthening chisel plough bits cast from gray cast iron is proposed, which allows to increase their wear resistance. Replacing expensive materials, alloys and technologies with non-alloyed cast iron with a wear-resistant structure will significantly reduce the cost of working bodies of tillage machines. Proposals for the technology of obtaining castings for the manufacture of working bodies of tillage machines will improve their operational reliability.

1. Introduction
The works of a number of researchers have noted that the working bodies of tillage tools experience abrasive wear, i.e. there is micro-cutting by hard abrasive inclusions of the soil and fatigue destruction of micro-volumes, the intensity of which depends on the depth of processing, where there are fixed solid particles, and on the microstructure.

These particles are mineral crystals of quartz and granite (HV 7-11 GPA), which account for 36.6...70.8\% of the soil [1-4].

To increase the resource of working bodies of agricultural machinery, surfacing of wear-resistant alloys, saturation of the surface with metals and non-metals, use of ceramic materials, etc., but they are difficult to widely implement and very expensive, which repeatedly increases the cost of manufacturing parts. For example, the use of hard-alloy surfacing or alloying increases the relative wear resistance (compared to carbon steel) by 10 times, but is accompanied by a 40-fold increase.

Some foreign manufacturers, including, for example, the well-known American firm "John Deere", develop a promising direction of manufacturing chisel ploughs by casting from high-strength cast iron with spherical graphite, using proprietary technologies ADI (Austempered Ductile Iron) and CADI (Carbonic Austempered Ductile Iron) [5-12].
The purpose of this work was to provide high performance properties of chisel plough bits due to the optimal structuring of castings made of gray cast iron SCH 30 during heat treatment in comparison with metals widely represented in this segment.

The research was carried out on heat-treated samples (castings) of cast iron SCH30, steels 65G, 45 and Hardox 450 widely used for the manufacturing of tillage machines chisels. The parameters of heat treatment modes are given in the table.

The structures obtained as a result of heat treatment were examined with Neophot-21 metallographic microscope on micro-sections etched with 4% nital. The local hardness of the hardened zones as well as the individual structural components were determined using a PMT-3 device. The total Brinell and Rockwell hardness, as well as Charpy impact strength, were determined by standard methods according to GOST 9012-59, 9013-59 and 9454-78, respectively.

2. Materials and methods
The method of research provided for comparative laboratory tests of the iron and steel under study, heat-treated in different modes, for abrasive wear resistance. The tests were carried out on the friction end machine in accordance with the requirements and recommendations of GOST 17367-71.

| Sample number and material | Heat Treatment Modes Parameters |
|----------------------------|---------------------------------|
| No. 1. Cast iron SCH30    | Regarding mode No. 2 + high frequency current quenching (high frequency current) with reflow of the working surface |
| No. 2. Steel 65G          | Quenching from t = 820 ° C, then cooled in oil and tempering at t = 350 ° C |
| No. 3. Steel 45           | Normalization at t = 880 ° C for τ = 2 hours, then air cooling |
| No. 4. Steel Hardox 450   | Heat treatment by the manufacturer |

A stationary sample was pressed to the surface with a carborundum abrasive fixed on it, grain size being 100-125 microns with a force of 39.2 N. The abrasive surface moved against the sample at the speed of 1.0 m/s. The total test time for each sample amounted to 5 minutes, the mass wear of the sample being measured every minute of the test. The wear resistance of the samples was evaluated according to the relative wear resistance ε equal to the ratio of the mass loss of the test sample Δm to the weight loss of the reference sample Δm under the same wear conditions, respectively.

Steel 45 chisels are widely represented in the spare parts market. In comparative tests for wear resistance, this steel was used as a reference, its wear resistance being taken as 1.

Chisels made of steel and cast iron and heat-treated according to experimental conditions were subjected to field trials in the autumn period of deep treatment on chestnut (Calcic Kastanozem) soils of medium grain size in the state of their physical ripeness. The total area of plowing amounted to 400 ha. The experimental chisels were installed on one unit and were replaced with serial ones as they failed. A sharp decrease in the depth of processing (tool depth), as well as ultrahigh traction resistance of the tool during the test were the indicators for culling chisels according to the criterion of limiting wear.

3. Results
Hardening the SCH30 cast iron sample and creating a chilled layer consisting of cementite eutectic - ledeburite on its surface were carried out by local rapid heating to melt the metal during high-frequency hardening (sample 1). Affected by heat, the bulk of the metal remained cold. Therefore, the heat source having been disconnected, the thin molten surface layer, due to intensive heat removal to a large cold mass, solidified with a strong super-cooling with regard to the eutectic solidus with the formation of ledeburite.

The micro hardness of the chilled ledeburite layer formed on SCH30 cast iron (sample 1) equaled to H50 = 10210 ± 1403 MPa. The main difference was the thickness of the chilled layer. In the process of heating, the chilled layer was 1.2 mm or more (figure 1).
Figure 1. Microstructure of chilled layer, obtained as a result of fusion and rapid cooling of cast iron SCH30 surface, high-frequency current (× 500).

Sample No. 2 of 65G steel after quenching and tempering had a microstructure of tempered medium needle martensite (score 5 according to GOST 8233-56) (figure 2, a), the hardness was HRC 47 ± 1.8, and the impact toughness of KCU was 31 J / cm2. The microstructure of sample No 3 of steel 45, which is most widely used in manufacturing plow chisels, is a relatively homogeneous mixture of ferrite and pearlite grains, characteristic of the normalized state (figure 2, b); steel hardness is HB 185 ± 2, 1.

Hardox 450 steel (sample 4) was not subjected to heat treatment in the manufacture of the bit, since it is supplied in a heat-treated condition, the manufacturer does not disclose heat treatment modes. The microstructure of Hardox 450 steel is a highly dispersive trophic-sorbitol (figure 2, c); the steel hardness is HB 411 ± 4.7.

The dynamics of weight loss by samples of experimental materials when testing for abrasive wear is shown in figure 3.

Figure 2. Microstructures of samples No 2-4 (× 100): a – steel 65G in the state of hardening and release, b – steel 45 after normalization; c – steel Hardox 450 in the shipment state.
The test results showed (figure 3) that grey and high-strength cast irons with a chilled working surface have the greatest and close-in wear resistance, which is a multiple of the wear resistance of the other materials under study. So, for cast iron SCH 30 after quenching with high frequency currents $\varepsilon = 4.14$.

Hardox 450 steel ($\varepsilon = 1.98$) showed resistance to wear, commensurate with the results of 65G steel ($\varepsilon = 2.05$), heat-treated to a hardness of similar magnitude.

Operational tests carried out throughout the season of autumn deep tillage, revealed some features of wear resistance test chisels. They showed that the time between the chisels of Hardox 450 steel and the maximum allowable wear of the working edge did not exceed 4 hectares. Resource chisels from hardened steel 65G amounted to 18-20 hectares. The maximum resistance was shown by chisel from grey cast iron SCH 30, chilled by reflow when heated by an electric arc. They stood for the whole season, not having exhausted their resources during the development of 100 hectares. A dramatic increase in the resource of chisels with a chilled layer is caused not only by the high wear resistance of the actual ledeburite layer, but is obviously associated with the implementation of the self-sharpening effect of the cutting edge during operation due to the significant difference in the side surfaces of the wedge for wear resistance.

Observations on the course of testing have shown that in actual operation in field conditions, the wear of grey iron chisels with lamellar graphite and chilling of the cutting part is accompanied by breaking of the cutting edge and is much more intensive than that of high-strength nodular graphite, which is gradually abrading.

4. Conclusion
Getting local chill on the cutting edge of the bit is achieved by heating the working surface to melt a thin surface layer of a predetermined thickness of high frequency current or an electric arc and then cooled with a water shower. The use of grey cast iron for the manufacture of plow chisels in comparison with the presented samples is justified by the high wear resistance of the chilled layer. The use of Hardox 450 steel for the manufacture of plow chisels provides advantages in wear resistance neither to chilled cast-iron working bodies from SCH 30 nor to domestic low-alloy steels with a carbon content of 0.45-0.65%.

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References

[1] Motorin V A, Gapich D S, Borisenko I B and Kurbanov D B 2020 Simulation of the Wear of the Working Bodies of Chisel Plows *Journal of Friction and Wear* **41**(1) 71–77

[2] Borisenko I B, Pyndak V I and Novikov A E 2012 The Development of Chisel Tillage Tools and their Theoretical Justification *Machine and Technology Station* **3** 16-20

[3] Ovchinnikov A S, Mezhevova A S, Novikov A E, Fomin S D, Pleskachev Yu N, Borisenko I B, Zvolinsky V P, Tyutyuma N V and Vorontsova E S 2017 Energy and Agrotechnical Indicators in the Testing of Machine-tractor Units with Subsoiler *ARPN Journal of Engineering and Applied Sciences* **12**(24) 7150-7160

[4] Kostyleva L V, Gapich D S, Motorin V A and Novikov A E 2019 Microstructure and abrasive wear resistance of heavy duty parts from high-strength cast iron in chisel plows *Chernye Metally* **3** 37-42

[5] Makarenko K V 2010 On Obtaining from Cast State of Half-cast Irons with Ausferrite *Structure Foundry* **2** 2-6

[6] Novikov A E, Motorin V A, Lamskova M I and Filimonov M I 2018 Composition and Tribological Properties of Cutting Blades of Tillage Machines under Abrasive Deterioration *Journal of Friction and Wear* **39**(2) 158-163

[7] Motorin V A, Kostyleva L V and Gapich D S 2020 Increasing Wear Resistance of Chisel Tools Working Bodies Based on Improving the Metallographic Structure of Grey Cast *Solid State Phenomena* **299** 652-657

[8] Kanatieva A V, Morozov D A and Kondrashov A V 2017 Analysis of potato cultivation technologies in difficult soil and climate conditions of the Russian Federation / A.V. Kanatieva *Young scientist* **11.3** 10-12

[9] Maximov P L 2002 New working bodies and machines for the production of root crops: monograph *Izhevsk: Publishing house Irgskha* 80 p.

[10] Borisenko I B, Pyndak V I and Novikov A E 2012 The Development of Chisel Tillage Tools and their Theoretical Justification *Machine and Technology Station* **3** 16-20

[11] Motorin V A, Gapich D S and Novikov A E 2019 Improvement of wear resistance of working elements from gray iron for development of the ground *IOP Conf. Series: Earth and Environmental Science* **341** 012138

[12] Kostyleva L V, Gapich D S, Novikov A E and Motorin V A 2020 Wear-Resistant Cast Iron Containing Spheroidal Graphite with a Two-Layer Ledeburitic–Martensitic Shell *Russian Metallurgy (Metally)* **3** 231–237