Investigation of plasma metal-ceramic coatings on cutting surfaces of working bodies of machines and mechanisms

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Abstract. The article describes the innovative method of strengthening the working organs of soil-cultivating machinery, which are operated in an abrasive medium. It is performed by carbo-vibro-arc surfacing of working bodies using composite metal ceramic pastes with simultaneous thermodiffusion hardening of basic metal of the working body. Based on the results of the studies, the optimum composition and concentration of pasta components were determined, which ensure an increase in wear resistance of hardened working organs by an average of 1.8 ... 2.0 times.

1. Introduction

Working bodies of national and international tillage machines (shares, chisels, land-sides, shellboards, blades and pointed and chisel-shaped hoes, smooth and toothed disks, etc.) are operated in the conditions of direct impact of abrasive particles. As the result they are strongly worn out, their cutting surfaces grow blunt, considerable changes in form, profile and working dimensions. For example, mean life of plow shares of Russian production is 5…20 ha depending on soil types and their structure, mean life of plow shellboards is 20…100 ha, of land-sides is 20…60 ha, of cultivators pointed hoes and sowing machines is 10…40 ha, of harrow disks and stubble plows is 8…20 ha [1-3]. Utilization of worn working bodies results in reduction of the field works quality; agrotechnical terms violation, increase in machine fault time and growth of costs on soil processing and greases, reduction of amount of the obtained market products.

Modern innovative method carbo-vibro-arc hardening (CVAH) with application of graphite electrode and composite metal ceramic pastes allows the considerable increase of tillage tools wear resistance being operated in abrasive medium. The method subject-matter is in the following. At first, paste is applied on the working element cutting edge, which is dried to hardening. Then, electric arc between the surface with the applied paste under hardening and graphite electrode of the device strikes. When it burns, surfacing of metal ceramic coating obtained from paste components as well as thermodiffusion saturation of working bodies metal with alloy elements which are included into the paste composition and with carbon at the expense of its diffusion that results from graphite electrode sublimation takes place [4-6]. Application of metal ceramic materials in the paste form at carbo-vibro-arc hardening (CVAH) is determined by their high resistance to abrasive and mechano-corrosive wear.

2. Methods.
Paste content includes steel matrix (surfacing powder), aluminum oxide Al$_2$O$_3$, silicone dioxide SiO$_2$, boron carbide B$_4$C, which are ceramic components, and also the substances containing nitrogen (ammonium nitrate NH$_4$NO$_3$, carbamide NH$_2$CONH$_2$ etc.), and cryolite Na$_3$AlF$_6$, improving stability and quality of arc burning [1, 4]. Adhesive substance is 50% water solution of PVA glue. It was proved that the paste components considerably influence the hardness and wear resistance of the hardened surfaces. To determine paste composition we carried out the corresponding investigations. Pastes with above mentioned components in different proportions were prepared by mechanical mixing. Powder PG-10N-01 was used as matrix material. The content of cryolite Na$_3$AlF$_6$ in all analyzed pastes was accepted as 10% [4]. The pastes were applied on the samples produced from steel 65G. This steel type selection was determined by the fact that it is used for the majority of working bodies and other machinery, working in the abrasive wear conditions. Thickness of applied paste layer was 2.5…3.0 mm. Then pastes were dried at temperature 90…95°C to hardening. Usually the setting time does not exceed 8…10 min.

Device VAGH-2 (vibro-arc-graphite hardening) that is developed and is produced in Federal State Budget Research Establishment of State Scientific Technological Institute of All Russian Research Technological University was used for CVAH (carbo-vibro-arc hardening). Sample hardening was done in the following modes: current intensity I=70…80 A, voltage U=60 V, vibration frequency of graphite electrode is 25 Hz. The surfaced coating thickness was on the average 0.8 mm.

3. The results of the research.

The results of studies to determine the microhardness of hardening coatings deposited on samples are presented in Figures 1 .. 4.

![Figure 1](image_url)

Figure 1 – Changing of HV microhardness of the coating being surfaced in depth h depending on the content of aluminum oxide Al$_2$O$_3$: 1 – Al$_2$O$_3$ - 30%; 2 – Al$_2$O$_3$ - 20%; 3 – Al$_2$O$_3$ - 10%; 4 – Al$_2$O$_3$ - 35% in paste.
Figure 2 – Changing of HV microhardness of the coating being surfaced in depth h depending on the content of silicone dioxide SiO\(_2\): 1 – SiO\(_2\) - 30%; 2 – SiO\(_2\) - 20%; 3 – SiO\(_2\) - 10%; 4 – SiO\(_2\) - 35% in paste.

Figure 3 – Changing of HV microhardness of the coating being surfaced in depth h depending on the content of boron carbide B\(_4\)C: 1 – B\(_4\)C - 30%; 2 – B\(_4\)C - 20%; 3 – B\(_4\)C - 10%; 4 – B\(_4\)C - 35% in paste.
Figure 4 – Changing of HV microhardness of the coating being surfaced in depth h depending on the content of ammonium nitrate NH$_4$NO$_3$: 1 – NH$_4$NO$_3$ - 30%; 2 – NH$_4$NO$_3$ - 20%; 3 – NH$_4$NO$_3$ - 10%; 4 – NH$_4$NO$_3$ - 35% in paste

Analysis of the data obtained proved that with the increase of percentage content of ceramic components in paste from 10% to 30% microhardness of the surfaced coating also increases regardless the used ceramic component. At the same time the maximum average value of microhardness (1508 HV, that corresponds to microhardness 75 HRC) were showed by the samples being surfaced with the paste containing 30% of boron carbide B$_4$C (Figure 3, curve 1). The obtained coating hardness on the average by 1,5…1,7 times exceeds hardness of tempered steel 65G, from which the majority of series produced working bodies are made. It is connected with the following that boron carbide is one of the hardest materials and according to its hardness it gives place to diamond and borazon (boron nitride). Pastes containing 30% of aluminum oxide Al$_2$O$_3$ and silicone dioxide SiO$_2$, were characterized by lower values of coatings microhardness – 991 HV (69 HRC) and 922 HV (67 HRC) correspondingly (Figures 1, 2). It can be explained that at surfacing as the result of arc high temperatures influence subsolution of Al$_2$O$_3$ and SiO$_2$ with the corresponding coating hardness reduction takes place.

The samples being hardened with application of pastes containing ammonium nitrate NH$_4$NO$_3$, were characterized by the minimum values of coatings microhardness, that does not depend on the above mentioned component content. At the same time the maximum average value of microhardness (763 HV, that corresponds to hardness 62 HRC) was obtained at paste content of 30% NH$_4$NO$_3$ (Figure 4, curve 1).

4. Conclusion.

Thus, the described investigations proved that the paste containing 30% of boron carbide, 60% of matrix powder and 10% of cryolite is the most optimal paste for hardening of tillage tools, being operated in abrasive medium. The results of the comparative tests of the samples after hardening by such a paste and unhardened samples from tempered steel 65G showed that wear resistance after hardening increases by 1,8…2,0 times.
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