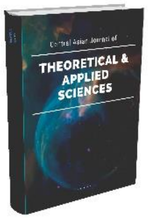

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Hardness and Wear Resistance of Heat-Treated Steel Parts of Tillage Machines

Sherbotaev Jamshid Abdurazzokov
Senior lecturer of Almalik Branch Tashkent State Technical University named after Islam Karimov, Uzbekistan, Region Almalik
jamshidsherbotayev@gmail.com

Tilabov Bahodir Kurbanovich
Doctor of technical sciences, professor Almalik branch Tashkent State Technical University named after Islam Karimov, Uzbekistan, region Almalik
btilabov@mail.ru

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Abstract: *The article deals with methods for determining the hardness and microhardness, as well as the wear resistance of hardened samples and parts of machines obtained by casting in earthen forms. The composition, properties and microstructure of carbon steel grade 45 were studied. The optimal modes of heat treatment of the deep-barker of tillage machines and mechanisms have been determined and applied. The results of abrasive wear of cast steel samples before and after optimal heat treatment (hardening with subsequent tempering) are given. It is shown that optimal heat treatment increases the hardness and abrasive wear resistance of cast steel parts of machines by 2-3 times.*

Keywords: *composition, properties and microstructure of steel, hardness, microhardness, modes of heat treatment, wear-resistance and longevity of parts.*

Introduction. Recommendations for the choice of standard materials for the manufacture of cast steel parts of machines subjected to abrasive and corrosive wear [1.2], as a rule, do not take into account the influence of general corrosion processes, the contribution of which to the overall wear of parts of machines and mechanisms with a relatively low level of external micro-wear is very significant. Therefore, the study of the laws of abrasive and corrosive wear in corrosive environments is of great scientific and practical importance.

Many parts of machines and mechanisms work in conditions of abrasive and corrosion wear, when the material of the part requires both abrasive wear resistance and corrosion resistance. The service life of these parts is limited due to the simultaneous abrasive and corrosive effects of the environment [3]. All this requires constant updating of the fleet of technological equipment and spare parts.

Objects and methods of research. The object of the study is the ploughshare of the deep-leaved excavator, working in soil conditions under the influence of an abrasive environment. These parts work in hard soil conditions and fail as a result of abrasive wear. The purpose of the work is the technology of manufacturing the ploughshare of the deep-leaver of tillage machines by casting into earthen molds and their subsequent optimal heat treatment. It consists in establishing the possibility of effective hardening of the surface and increasing the hardness and wear resistance of cast parts made of steel 45 by treating their working surface with reliable optimal thermal hardening [4].

Most parts of machinery and equipment that work in direct contact with the soil (or metal with metal) are subjected to surfacing with hard alloys. This requires the use of rather complex technological equipment associated with a large consumption of scarce hard alloys and fluxes. It is more rational to produce these parts by casting in earthen molds with simultaneous smooth surface production of cast machine parts [4].

The obtained results and their discussion. As quick-wearing parts, they took a small-sized ploughshare of the deep-leaver of tillage machines operating in soil conditions under the influence of an abrasive environment [5]. Therefore, the working surfaces of such parts are subjected to surface hardening by heat treatment. The paper explores the composition, properties, microstructure, hardness and abrasive wear of machine parts obtained by casting into earthen forms before and after optimal heat treatment (hardening with subsequent release) [6]. This hardening and tempering is like an anti-wear coating. The samples were made of steel 45 in such a way that there were parts with high hardness on the working surface. This hardening has a low heating temperature of 825-830^{0}C, and the parts have a relatively high hardness and wear resistance. The choice of carbon steels as the object of research is due to the need to study the effect of optimal heat treatment in the structure and on the abrasive wear resistance of steel parts [4.6].

The technology of manufacturing parts by casting in earthen molds includes obtaining a cast blank. After drying the mixture, the models were formed in quartz sand (at the same time sealing by pneumatic vibration occurs) and poured with liquid metal corresponding to the composition of steel 45 at a temperature of 1600-1650^{0}C through a sprue system with a siphon supply of metal. When pouring, the model was filled and the casting surface was saturated with carbon up to 0.7%. In this way, the casting of the part of the deep-leaver's ploughshare is obtained [6]. Filling the mold with liquid metal is one of the main stages in the formation of the casting of machine parts, which determine many indicators of its quality. When the insert contacts the liquid metal, a solid casting crust is formed, the insert melts, the liquid phase of the insertion interacts with the crust material and, after crystallization, the formation of eutectic or beyond the eutectic compositions on the surface of the carbon steel structure [7.8]. The transition from the surface to the base metal is quite sharp, although there are transition zones from beyond the eutectic part to the eutectic, pre-eutectic and to the zone of beyond the eutectic carbon steel. A zone of the eutectic structure of high-carbon steel is formed on the surface of the samples, and further along the depth there are pre-eutectic and eutectoid zones that pass into the structure of the base metall.

Macro and micro researches were studied with optical metallographic microscopes MBS-1, MBS-9, MIM-8M and Neofot-21. Samples for research were four-square and round with dimensions of 12x12, 15x15, 15x20, 20x20, 22x22 mm.

The microstructure and microhardness of carbon steels change significantly after heat treatment. If the hardening is carried out from a heating temperature of 825^{0}C, then the perlite component of the structure experiences a martensitic transformation. The location of the carbide component does not change. For example, after hardening with a heating temperature of 825^{0}C and 830^{0}C of steel samples, the structure of the eutectic component and the location of secondary carbides did not change. Only instead of a perlite component, fine-needle “martensitis” is observed.

When heated for hardening to a temperature of 810-815^{0}C, all secondary carbides are dissolved in “austentite”, only primary carbides remain in the eutectics. In some samples obtained by casting in earthen molds, a structure consisting of eutectic carbides and martensite forms on the surface. On the microstructure, martensitic needles, residual austenite, primary carbides and sublayers of high-carbon "martensite" are clearly visible (fig. 1, a, b, c) [4.6].

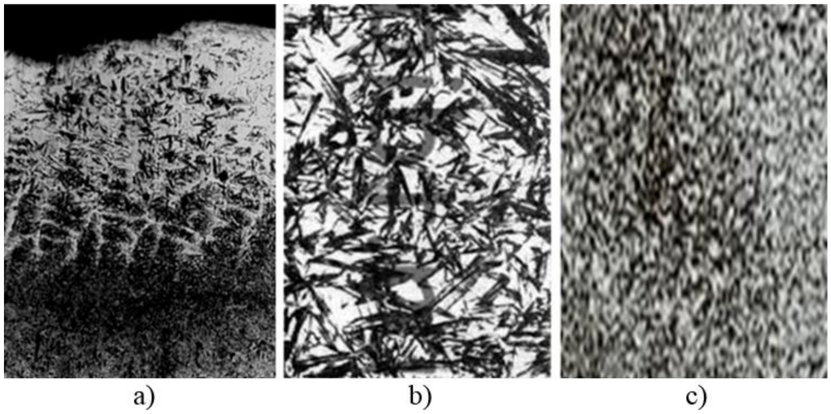

Fig.1. Microstructure of carbon steel after optimal heat treatment: **a**-high carbon sublayer with fine-needle structure; **b**-coarse-grained "martensite"; **c**-fine-grained "martensite". X500

The hardness of the samples was determined on Brinell TVB-4 and Rockwell TK-2 devices. The hardness of annealed steel samples was measured by Brinell (HB) and hardened by Rockwell (HRA, HRC and HRB at different loads). As a rule, the hardness of soft metals is tested by a steel ball, and hard metals - with a diamond cone. According to the Rockwell method, the depth of the imprint was determined. The tip was a diamond cone with an angle at a top of 120° and a steel hardened ball with d = 1.588 mm.

The microhardness of some HDTV-hardened samples was measured on the PMT-3 device at a load of 0.5 N. Microhardness varies widely after heat treatment, and the highest microhardness in samples hardened to HDTV at the optimum temperature. At the surface itself, a pre-eutectic structure is formed with a large number of primary chromium carbides with a hardness HV_{100} = 15300 MPa. At the same time, the microhardness of the perlite component of eutectics is 7300 MPa [6]. This method is important for steel parts of small sizes and individual structural components of metals and their alloys.

For the study of phase X-ray diffraction analysis, steel samples with dimensions of 15x20, 20x20 and 22x22 mm were taken on a DRON-2.0 diffractometer. The results of phase X-ray diffraction analysis give a more complete picture of the composition of the obtained steel samples and parts. The width of the X-ray lines was determined at half the height of the maximum as the arithmetic mean of four to five diffractograms or X-ray intensity distribution curves. Calculations of measurement errors showed that they are in the range of 5-10%, depending on the object of research. According to the results of scientific research, it was revealed that special carbides of the type Me_7C_3, $Me_{23}C_6$, etc. are formed on the working surface of samples with hardened layers.

Comparative tests for abrasive wear resistance on the fixed abrasive were carried out at the laboratory unit of the PV-7 friction machine [9]. Relative wear resistance was determined by weight loss of the cast sample standard, and the relative wear resistance of cast test specimens was determined by weight methods (VLA 200-M) after each abrasive wear test. All samples before and after optimal heat treatment were tested for abrasive wear resistance. Tests for abrasive wear of samples in time were carried out on the friction machine PV-7 with an unsecured abrasive material. The test results are presented in Tables 1 and 2. Optimal heat treatment increases the wear resistance of samples and parts: the larger the hardened zone, the smaller the amount of wear of the parts. The results of the abrasive wear test of cast samples No. 01 and No. 02 before and after optimal heat treatment are given in table 1.

Table 1. Abrasive wear of cast sample No. 01 before heat treatment

No p/n	Stamp of steel	The time of tests, min	Wear before the test, g	Wear after the test, g	The difference of wear before and after the test, g
1.	45	30	139.8694	139.8677	0.0017
2.	45	30	139.8677	139.8666	0.0011
3.	45	30	139.8666	139.8659	0.0007
4.	45	30	139.8659	139.8655	0.0004
5.	45	30	139.8655	139.8653	0.0002
6.	45	30	139.8653	139.8653	0.0000
Cast sample No. 02 before heat treatment					
1.	45	30	140.7990	140.7974	0.0016
2.	45	30	140.7974	140.7964	0.0010
3.	45	30	140.7964	140.7957	0.0007
4.	45	30	140.7957	140.7952	0.0005
5.	45	30	140.7952	140.7949	0.0003
6.	45	30	140.7949	140.7949	0.0000
Cast sample No. 01 after heat treatment					
1.	45	30	137.7788	137.7781	0.0007
2.	45	30	137.7781	137.7776	0.0005
3.	45	30	137.7776	137.7774	0.0002
4.	45	30	137.7774	137.7774	0.0000
Cast sample No. 02 after heat treatment					
1.	45	30	138.8379	138.8373	0.0006
2.	45	30	138.8373	138.8370	0.0003
3.	45	30	138.8370	138.8369	0.0001
4.	45	30	138.8369	138.8369	0.0000

The results of the abrasive wear test of cast samples No. 03 and No. 04 before and after optimal heat treatment are presented in table 2.

Table 2. Abrasive wear of cast sample No. 03 before heat treatment

No p/n	Stamp of steel	The time of tests, min	Wear before the test, g	Wear after the test, g	The difference of wear before and after the test, g
1.	45	30	143.6684	143.6669	0.0015
2.	45	30	143.6669	143.6658	0.0011
3.	45	30	143.6658	143.6651	0.0007
4.	45	30	143.6651	143.6647	0.0004
5.	45	30	143.6647	143.6646	0.0001
6.	45	30	143.6646	143.6646	0.0000
Cast sample No. 04 before heat treatment					
1.	45	30	143.5880	143.5862	0.0018
2.	45	30	143.5862	143.5849	0.0013
3.	45	30	143.5849	143.5843	0.0006
4.	45	30	143.5843	143.5839	0.0004
5.	45	30	143.5839	143.5837	0.0002
6.	45	30	143.5837	143.5837	0.0000

Cast sample No. 03 after heat treatment					
1.	45	30	140.1834	140.1828	0.0006
2.	45	30	140.1828	140.1824	0.0004
3.	45	30	140.1824	140.1822	0.0002
4.	45	30	140.1822	140.1822	0.0000
Cast sample No. 03 after heat treatment					
1.	45	30	140.4340	140.4335	0.0005
2.	45	30	140.4335	140.4332	0.0003
3.	45	30	140.4332	140.4331	0.0001
4.	45	30	140.4331	140.4331	0.0000

As can be seen from the above tables 1 and 2, our tests for abrasive wear of special samples with smooth surfaces are fully consistent with the results of field tests, which really increase the wear resistance of parts after optimal heat treatment by two or more times. The hardness of the heat-treated samples reaches up to HRC56-59. In this position, the perlite component of the structure experiences a martensitic transformation. The final structure has a purely martensitic structure with a fine-needled and fine-grained structure (fig.2, a, b, c) [6.9]. Thus, the long and narrow sections of the austenitic grain along the shear line with the alpha lattice are a plate of martensite, which on the plane of grinding has the appearance of a long thin needle. Needle activity is a very characteristic microstructural feature of martensite (sm. fig.2).

The technologies developed by us for the manufacture of cast parts of machines for casting in earthen molds and the use of optimal heat treatment were used in the production of a pilot batch of cast parts and tested in the field in various regions and districts of the republic.

The results of field tests showed an increase in the wear resistance of cast steel parts without heat treatment, sealing and processing stability up to one and a half times, and after the final optimal heat treatment by two or more times than serial parts [10-14]. Therefore, such cast steel ploughshares of the deep-penetrating tillage machines have a surface hardness according to Rockwell 57-59HRC. The hardness of all hardened samples was determined by HRA, HRC and HRB under different loads. Heat treatment has a good effect on the hardness and wear resistance of steel [10].

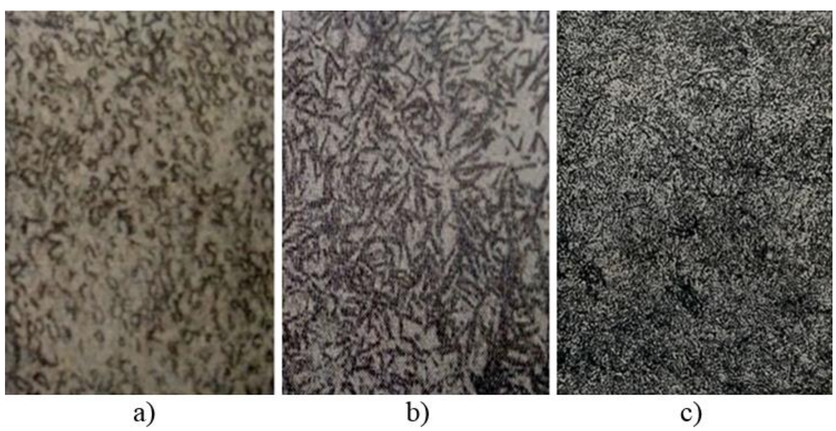

Fig.2. Microstructure of carbon steels: **a**-correctly hardened steel; **b**-coarse-needle “martensite”; **c**-fine-needle “martensite”. X500

***Conclusion*.** In connection with the foregoing, it can be concluded that an effective way to increase hardness and abrasive wear resistance is to apply optimal heat treatment modes (hardening with subsequent release). Such heat treatment forms an optimal structure with a high density of dislocations, dispersed secondary and coagulated primary carbides - fine-grained martensitic structures. From the above data it can be seen that optimal heat treatment increases the abrasive wear resistance of finished cast parts by 2.5-3.0 times higher than serial products. This innovative technology was introduced in JSC "Aggregate Plant" and an act of implementation with an economic effect was obtained.

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