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Investigation of Working Capacity and Wear Resistance of Surface Coatings of Cast Steel Machine Parts

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Abstract: This article discusses wear-resistant materials for cast steel parts of machines and equipment used in automotive and agricultural machinery construction. Special samples with a wear resistant hard-alloy coating with a layer thickness of 2-3 mm or more, obtained by casting on expanded polystyrene gasified models, are presented. The chemical compositions of various steel grades studied are given. Tests for abrasive wear of samples were performed before and after optimal heat treatment with double phase recrystallization. It is shown that optimal heat treatment with double phase recrystallization increases the hardness and wear resistance of cast samples and parts by 3-4 times in comparison with serial products.

Keywords: gasified foam model, cast steel samples, wear resistant hard-alloy, hard-alloy coating, heat treatment with double phase recrystallization, quenching, tempering, microstructure, hardness of samples, abrasive wear resistance and durability of parts.

INTRODUCTION

One of the most important tasks of agricultural engineering is to improve the operational properties and qualities, as well as extend the service life of machine parts and mechanisms [1]. This requires extensive use of strong and wear resistant materials based on a hard-alloy such as “sormayt (alloying material)” PG-S27 [2], as well as the introduction of new modern technological methods that improve the operational properties and increase the service life of the machine parts and equipment.

Most machine parts used in the automotive and agricultural machinery industry fail due to intensive abrasive-corrosive hit-abrasive wear [3] of the main parts of machines and mechanisms. One of the simplest and most effective ways to extend the life of agricultural machines is to manufacture them from wear resistant hard-alloy likethe “sormayt” PG-S27 type by casting on expanded polystyrenegasified models [2,4].

This article presents materials on the study of abrasive wear resistance of medium-carbon and manganese steels.

Studies have shown that the resistance of metals to abrasive wear [2, 3] depends primarily on their chemical composition and mechanical properties, as well as on the optimal heat treatment. At the same time, wear resistance is closely related to the hardness of structural components and will be higher the higher their hardness and the more solid components there are in the alloy. Therefore, the abrasive wear resistance of steels can be significantly increased by alloying solid solutions and creating special carbides$_7C_3$, $M_{23}C_6$M7c3, M23c6, etc.

The available data on the wear resistance of various steels [5,6] in an abrasive environment is not sufficient for generalizations, so we had to study various steel grades in order to identify the relationship between the abrasive wear resistance of steel, its chemical composition, property, and microstructure [7,8].

Knowledge of such regularities would make it possible to reasonably choose the steel grade and assign the optimal heat treatment for machine parts operating under severe abrasive wear conditions.

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Research methodology. The following steel grades were selected for the study: carbon (steel 20, 25, 30), high-quality medium-carbon (steel 35GL, 40GL) and manganese (steel 65G).

Steels for the study were supplied in the annealed and quenched state with diameters of 70x30x15 and 70x35x15. The dimensions and shapeof the abrasive wear samplesare shown in fig.1.

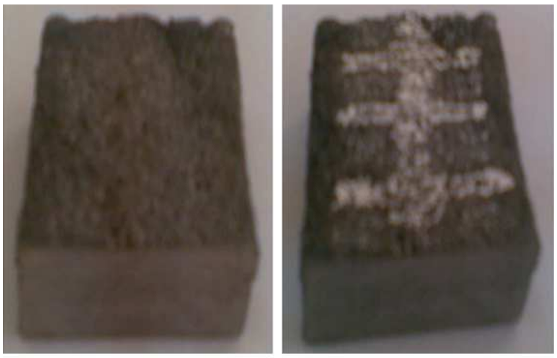

Figure.1. Special samples with a carbide coating thickness of 2.0-2.5 mm for testing for abrasive wear on the PV-7 friction machine: **a**-before testing; **b**-after testing.

The chemical composition of the steels is given in table.1.Special samples for testing for abrasive wear were made from all the steels specified in it. For this purpose, samples were selected from carbon steel (20,25,30) and cast samples from high-quality medium-carbon steel (35GL,40GL) obtained by casting using expanded polystyrene gasified models, as well as from manganese steel (65G) and subjected to various heat treatment modes (quenching from 900^0 to 1150^0C) and (vacation from 200^0 to 600^0S).

Table 1 Chemical composition of the studied steels

Steel grade	Element content, in % (max)						
	C	Si	Mn	Cr	Ni	P	S
carbon steel							
20	0,17-0,24	0,17-0,37	0,35-0,65	0,25	0,25	0,040	0,040
25	0,22-0,29	0,17-0,37	0,50-0,80	0,25	0,25	0,040	0,040
30	0,27-0,34	0,17-0,37	0,50-0,80	0,25	0,25	0,040	0,040
quality medium carbon and manganese steel							
35GL	0,32-0,39	0,17-0,37	0,70-0,95	0,28	0,27	0,040	0,040
40GL	0,37-0,44	0,17-0,37	0,75-1,0	0,28	0,27	0,040	0,040
65G	0.62-0,70	0,17-0,37	0,90-1,20	0,28	0,27	0,040	0,040

Research results and discussion. All samples with a hard-alloy coatingwere tested for abrasive wear resistance before and after thermal treatment with double phase recrystallization [8,9]. These samples were tested in turn for abrasive wear on a PV-7 friction machine with loose abrasive materialлом. The test time for each sample is 30 minutes. For experimental cast samples with a coating, the tests were repeated 5-6 times, and for standard steels (samples) – 6-8 times. A hard-alloy coating dramatically increasesthe wear resistance: the greater the thickness of the coating, the smaller the amount of wear. The results of testing the abrasive wear of samples made of steel 20,25,30 and cast samples 35GL, 40GL, and 65G before and after heat treatment are shown in Tables 2-3.

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Table 2 Abrasive wear of carbon steels

№ n/a	Steel grade	Test time, min	Wear before testing, g	Wear after testing, g	Wear difference before and after the test, g
Abrasive wear of carbon steel No. 01 before heat treatment					
1.20	20	30	141.22663	141.2230	0.0033
2.	20	30	141,2230	141,2202	0,0028
3.	20	30	141,2202	141,2179	0,0023
4.	20	30	141,2179	141,2161	0,0018
5.	20	30	141,2161	141,2148	0,0013
6.	20	30	141,2148	141,2140	0,0008
7.	20	30	141,2140	141,2136	0,0004
8.	20	30	141,2136	141,2136	0,0000
Abrasive wear of No. 02 carbon steel before heat treatment					
1.25	25	30	142.2854	142.2824	0.0030
2.	25	30	142,2824	142,2800	0,0024
3.	25	30	142,2800	142,2781	0,0019
4.	25	30	142,2781	142,2767	0,0014
5.	25	30	142,2767	142,2757	0,0010
6.	25	30	142,2757	142,2750	0,0007
7.	25	30	142,2750	142,2747	0,0003
8.	25	30	142,2747	142,2747	0,0000
Abrasive wear of No. 03 carbon steel before heat treatment					
1.30	30	30	143.4897	143.4770	0.0027
2.	30	30	143,4770	143,4748	0,0022
3.	30	30	143,4748	143,4731	0,0017
4.	30	30	143,4731	143,4718	0,0013
5.	30	30	143,4718	143,4708	0,0010
6.	30	30	143,4708	143,4701	0,0007
7.	30	30	143,4701	143,4698	0,0003
8.	30	30	143,4698	143,4698	0,0000
Abrasive wear of cast sample No. 1 with a coating thickness of 2.0 mm before heat treatment					
1.	35GL	30	144,4095	144,4078	0,0017
2.	35GL	30	144,4078	144,4064	0,0014
3.	35GL	30	144,4064	144,4054	0,0010
4.	35GL	30	144,4054	144,4048	0,0006
5.	35GL	30	144,4048	144,4045	0,0003
6.	35GL	30	144,4045	144,4045	0,0000
Abrasive wear of cast sample No. 2 with a coating thickness of 2.5 mm before heat treatment					
1.	40GL	30	144,5498	144,5482	0,0016
2.	40GL	30	144,5482	144,5469	0,0013
3.	40GL	30	144,5469	144,5459	0,0010
4.	40GL	30	144,5459	144,5453	0,0006
5.	40GL	30	144,5453	144,5450	0,0003
6.	40GL	30	144,5450	144,5450	0,0000

Continuation of the table.2

Abrasive wear of cast experimental samples

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№ n/a	Steel grade	Test time, min	Wear before testing, g	Wear after testing, g	Wear difference before and after the test, g
Abrasive wear of manganese steel No. 04 before heat treatment					
1.	65G	30	144,4494	144,4471	0,0023
2.	65G	30	144,4471	144, 4451	0,0022
3.	65G	30	144,4451	144,4433	0,0018
4.	65G	30	144,4433	144,4419	0,0014
5.	65G	30	144,4419	144,4409	0,0010
6.	65G	30	144,4409	144,4403	0,0006
7.	65G	30	144,4403	144,4400	0,0003
8.	65G	30	144,4400	144,4400	0,0000

The results of testing the abrasive wear of samples after heat treatment are shown in table.3.

Table 3 Abrasive wear of carbon steels

№ n/a	Steel grade	Test time, min	Wear before testing, g	Wear after testing, g	Wear difference before and after the test, g
Abrasive wear of carbon steel No. 01 after heat treatment					
1.20	20	30	1386089	1386074	0.0015
2.	20	30	138,6074	138,6062	0,0012
3.	20	30	138,6062	138,6053	0,0009
4.	20	30	138,6053	138,6047	0,0006
5.	20	30	138,6047	138,6043	0,0004
6.	20	30	138,6043	138,6041	0,0002
7.	20	30	138,6041	138,6041	0,0000
Abrasive wear of No. 02 carbon steel after heat treatment					
1.25	25	30	137.7394	138.7390	0.0014
2.	25	30	137,7390	138,7378	0,0011
3.	25	30	137,7378	138,7369	0,0009
4.	25	30	137,7369	138,7362	0,0007
5.	25	30	137,7362	138,7357	0,0005
6.	25	30	137,7357	138,7355	0,0002
7.	25	30	137,7355	138,7355	0,0000
Abrasive wear of No. 03 carbon steel after heat treatment					
1.30	30	30	136.8498	136.8486	0.0012
2.	30	30	136,8486	136,8476	0,0010
3.	30	30	136,8476	136,8468	0,0008
4.	30	30	136,8468	136,8462	0,0006
5.	30	30	136,8462	136,8458	0,0004
6.	30	30	136,8458	136,8456	0,0002
7.	30	30	136,8456	136,8456	0,0000
Abrasive wear of cast sample No. 1 with a coating thickness of 2.0 mm after heat treatment					
1.	35GL	30	140,5387	140,5382	0,0005
2.	35GL	30	140,5382	140,5379	0,0003
3.	35GL	30	140,5379	140,5377	0,0002
4.	35GL	30	140,5377	140,5376	0,0001
5.	35GL	30	140,5376	140,5376	0,0000
Abrasive wear of cast sample No. 2 with a coating thickness of 2.5 mm after heat treatment					
1.	40GL	30	140,5893	140,5887	0,0006
2.	40GL	30	140,5887	140,5883	0,0004
3.	40GL	30	140,5883	140,5881	0,0002

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4.	40GL	30	140,5881	140,5880	0,0001
5.	40GL	30	140,5880	140,5880	0,0000

Continuation of the table.3

Abrasive wear of cast experimental samples

№ n/a	Steel grade	Test time, min	Wear before testing, g	Wear after testing, g	Wear difference before and after the test, g
Abrasive wear of manganese steel No. 04 after heat treatment					
1.	65G	30	140,6196	140,6186	0,0010
2.	65G	30	140,6186	140,6178	0,0008
3.	65G	30	140,6178	140,6172	0,0006
4.	65G	30	140,6172	140,6168	0,0004
5.	65G	30	140,6168	140,6166	0,0002
6.	65G	30	140,6166	140,6165	0,0001
7.	65G	30	140,6165	140,6165	0,0000

As can be seen from Table 2-3, our tests for abrasive wear of samples with a coating layer thickness of 2.0 and 2.5 mm fully correspond to the results of field tests (Table4), which actually increase the wear resistance of cast parts after heat treatment with double phase recrystallization by three and four times [8,9].

Based on the completed studies, four experimental batches of 20 parts in each batch were produced for field testing. The first batch was made using serial technology from steel 20, the second - from 35GL steel without hard-alloy coatings, the third-from 35GL steel with wear-resistant hard-alloy coating, the fourth-from 35GL steel with wear-resistant hard-alloy coating after heat treatment with double phase recrystallization. The wear value of the samples was determined by the weight method after the cultivator was operated during the time for processing 150-23230 ha of sown hectares. The relative wear resistance of the samples was also determined in comparison with serial parts. Field tests were conducted in different regions (districts) of the Republic of Uzbekistan and almost identical results were obtained (table 4).

Table 4 Field test results

№ n/a	Brands of test parts	Relative wear resistance
1.	Serial steel 20	1.0
2.	Experimental steel 35GL without coating	1,3
3.	Experimental steel 35GL with a coating	2,5-3,0
4.	Experimental 35GL coated Steel after heat treatment with double phase recrystallization	3,5-4,0

In accordance with this task, the aim of this work is to develop a technology for producing expanded polystyrene models and cast parts with high abrasive wear resistance. The object of research was the details of metallurgical and tillage machines, such as harrow teeth, tusk, cultivator legs, and rollers of metallurgical rolling equipment that experience intense abrasive wear when sliding on metal and soil.

The composition of wear-resistant hard alloys of the "sormite" type is investigated. The choice of the composition of the applied coating was made according to two criteria: **1**-the coating should meet the requirement of a 3-5-fold increase in wear resistance compared to the wear resistance of the steel base; **2**-the coating should include affordable and inexpensive components and differ in the simplicity of its application technology. Based on this, hard alloys of the "sormite" type of the PG-S27 brand were chosen as a coating on the working surface of the part. This alloy improves wear resistance and is particularly effective in abrasive wear conditions. When casting metal, the foam model burns out, and the casting surface is saturated with carbon up to 0.7% to a depth of 0.30.6 mm. When the coating of "sormite" powders comes into contact with liquid metal, a solid casting crust forms. Then the coating was melted and after crystallization, a wear-resistant hard-

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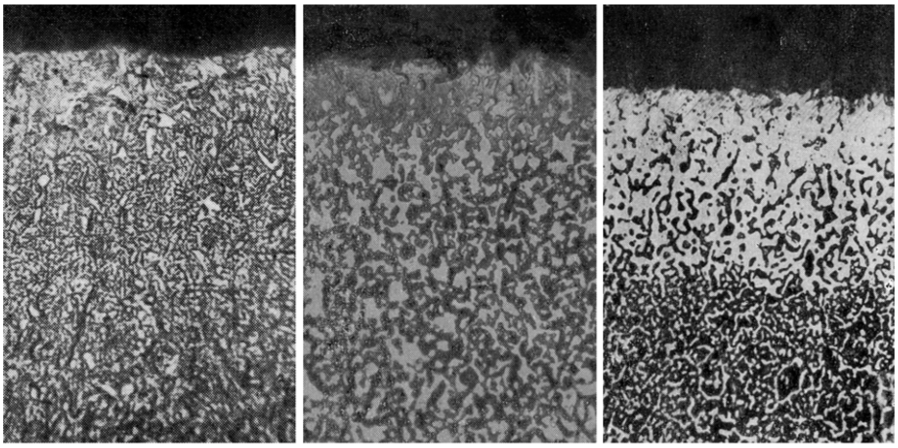
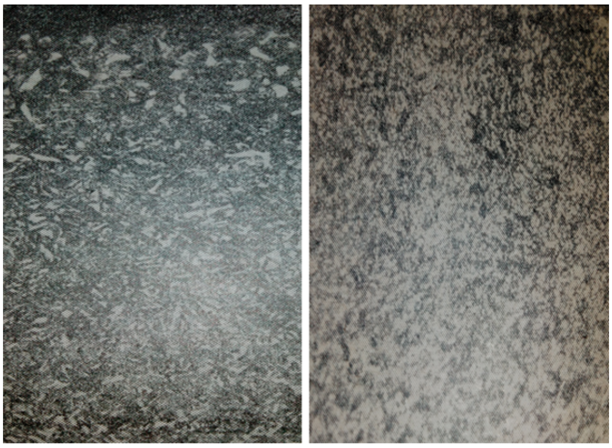
alloy coating with a layer thickness was formed on the casting surface 2,0-2,5-3,0 mm and with the structure [7] of a high-alloy alloy of eutectic and trans-eutectic composition (fig. 2). As a result of heat treatment, the surface layer should have the structure of fine-needle martensite (fig.3) with fine carbide or isolated areas (the smallest amount) of residual austenite.



a) b) c)

Figure.2. Microstructure of cast steel samples obtained with a wear-resistant carbide coating with a layer thickness of: **a**-2.0 mm; **b**-2.5 mm; **в**c-3.0 mm. X500

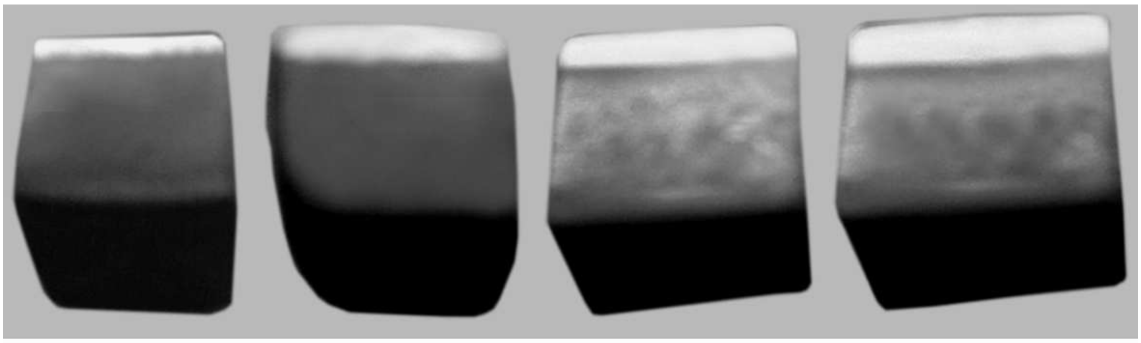
Thus, a multilayer composition was formed on the working surface, consisting of a high-alloyed layer of an alloy of non-eutectic and eutectic composition, passing in-depth into the zones of non-eutectoid and eutectoid steel and the base metal of 35GL steel. To check the surface thickness of the casting layer, a finished part with a wear-resistant carbide coating was taken, a section of the section was cut out for macro - and micro-examination, then it was sanded and polished, and then washed and etched with a special etcher to identify the surface carbide coating with a coating layer thickness from 2 to 4 mm.



a) b)

Figure.3. Microstructure of fine-needle martensite: **a**-normal quenched structure of X300; **b**- after quenching and tempering, the structure of fine-needle martensite with inclusions of globular fine carbides. X500

A more explicit and visual macro image of the surface hard-alloy “sormite” coatings from the cut samples is shown in (fig. 4a, b, c, d). The hardness of the surface layers of samples and finished parts reaches HRC58-62 [10], and the microhardness is up to 1800-2200 HV. In this case, the wear resistance and durability of cast parts after heat treatment with double phase recrystallization increase three and four times higher than that of serial parts.



a) b) c) d)

Figure.4. Specially prepared steel samples with a wear-resistant hard-alloy coating of the “sormite” PG-S27 type with a layer thickness of: **a**-2.0 mm; **b**-2.5 mm; **c**-3.0 mm; **d**-4.0 mm.

Conclusions. Based on the above, we can draw the following conclusions: the most effective way to increase abrasive wear resistance is to apply a hard-alloy coating to the working surfaces of the product when casting using gasified models. Heat treatment of a hard-alloy coating made of a high-chromium hard alloy of the “sormite”type, carried out with double phase recrystallization, formsan optimal structure with a high-density of dislocations, dispersed secondary and coagulated primary carbides. From the above data, it can be seen that heat treatment with double phase recrystallization increases [10] the abrasive wear resistance and durability of cast machine parts by 3-4 times higher compared to mass-produced products. This technology has been implemented in Uzmetkombinat JSC with a good economic effect.

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