Testing of heat-treated surfaced samples and machine parts for hardness and wear resistance

Bakhodir Tilabov[1*], *Akbarjon* Jumaev[2], *Jamshid* Sherbutaev[2], *Ulugbek* Normurodov[3], and *Giyosiddin* Salimov[2]

[1]Belarusian - Uzbek Intersectoral Institute of Applied Technical Qualifications, Uzbekistan
[2]Almalyk branch of Tashkent State Technical University named after Islam Karimov, Uzbekistan
[3]Tashkent State Technical University named after Islam Karimov, Uzbekistan

Abstract. In this article, the chemical and mechanical properties of some parts of machine mechanisms made of steel 35 are studied, as well as their resistance to abrasive wear. In addition, casting samples with corrosion-resistant surface coating obtained by casting are considered. The samples of steel material obtained as result of experimental studies and their resistance to corrosion in terms of hardness are presented using tables. The finished parts were tested for abrasive wear resistance in the field. Optimal modes of heat treatment with double phase recrystallization for parts of tillage machines have been applied. It is proved that the optimal heat treatment with double phase recrystallization increases the hardness and wear resistance of cast samples and finished parts by 2-3 times.

1 Introduction

It remains one of the important tasks to increase the periodicity of production of cast steel parts and increase the corrosion resistance of the product [1-3].

To date, the most important tasks for the manufacturer of tractor-agricultural machinery manufacturers are to improve the quality and increase the hardness and wear resistance of machine parts and mechanisms [4]. All this requires extensive use of durable and wear-resistant materials based on “sormite” PG-C27 surfacing powder [5], as well as the introduction of new modern technological methods that improve operational properties and increase the service life of machine parts.

Most of the parts used in the equipment of production enterprises and their mechanisms are prematurely repaired as a result of various loads, external shocks and abrasive wear [6-9]. In order to extend the service life of equipment and their components, it is recommended to use corrosion-resistant wool coating powders on the outer surface of the part [10].

Theoretical and experimental information on the study of hardness and resistance to abrasive corrosion of carbon and manganese steels was reviewed. The conducted scientific research shows that by heating the materials, it is possible to obtain a product resistant to eating by preserving their chemical and mechanical properties [11,12]. Corrosion resistance is closely related to the hardness of structural components, and the higher their hardness and

* Corresponding author: ozodbek4103@mail.ru

the higher the hardness components in the alloy, the greater the resistance to abrasive corrosion of steels can be significantly increased by alloying.

It is important to find the available information on the production of corrosion-resistant steels in manufacturing enterprises and to study their chemical and mechanical properties by summarizing them [13, 14]. By studying the microstructure of steels, it is possible to prevent their abrasive corrosion. As a result, it is possible to increase the periodicity of the equipment and its components [15].

The purpose of this work is to develop optimal heat treatment regimes with two-phase recrystallization of cast parts of soil tillage machines with wear-resistant surface coating of "sormit" PG-C27 type and subsequent high abrasive wear resistance. As a result, by conducting various experimental studies of the material, it is possible to increase the durability of the machine mechanisms by increasing their surface hardness and resistance to corrosion.

2 Methods

Medium-carbon (40, 45, 50, 30G, 40G, 50G) and high-quality steel 70G were selected for theoretical and experimental research. The chemical composition of these steels is given in the tables (Table 1). In order to check the abrasive wear, cast samples were prepared from all the above-mentioned steel grades. The sample of high-quality steel 70G was processed by heating twice (from 960º to 1100º C) and (from 450º to 750º C). As a result, the optimal mode of heat treatment (from 930º to 940º C) and (from 200º to 220º C) was selected [16,17].

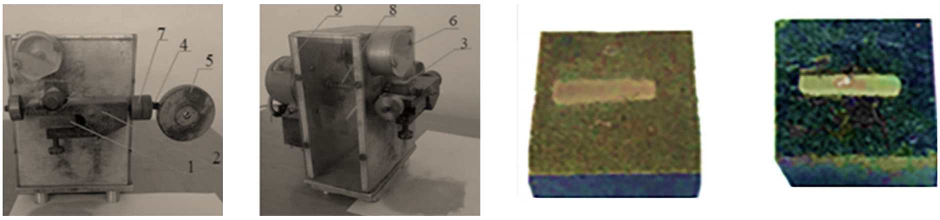
3 Double hardening

Samples after the first quenching from various heating temperatures and intermediate tempering 450º-600ºC were reheated to 900º-920ºC, quenched, cooled in oil and released at a temperature of 200ºC. Double hardening [18, 19] is used for the first time to increase the wear resistance of deposited cast parts. After double quenching, the hardness, microhardness and, especially, the wear resistance of the deposited parts increase by 10-15 % compared to serial products.

Table 1. Chemical composition of medium-carbon and high-quality steels.

Steel grade	The content of elements, %						
	C	Si	Mn	Cr	Ni	P	S
Carbon steels							
40	0.19-0.26	0.19-0.40	0.37-0.68	0.27	0.27	0.042	0.042
45	0.24-0.32	0.18-0.39	0.52-0.84	0.27	0.27	0.042	0.042
50	0.29-0.37	0.19-0.40	0.53-0.85	0.27	0.27	0.042	0.042
Medium carbon and manganese quality steels							
30G	0.34-0.42	0.17-0.39	0.72-0.97	0.29	0.28	0.042	0.042
40G	0.44–0.7	0.19-0.39	0.6 – 0.9	0.26	0.26	0.037	0.042
50G	0.62-0.70	0.19-0.39	0.92-1.23	0.29	0.29	0.042	0.042

Seasonal scientific research of abrasive wear of steels was conducted in experimental devices (Fig. 1, a, b). For this purpose, 80x40x20 mm samples were selected. Fig. 1 (c, d) shows the failed samples.



a b c d

Fig. 1. PV-7 friction testing machine (a, b): 1-sample; 2-holder; 3- polyurethane screw; 4-holder; 5-load; 6-quartz sand; 7-adjusting screws; 8-screw shaft; 9-reducer; and worn annealed samples (c) and hardened (d).

As a result of the conducted research, in order to increase the material's resistance to corrosion, test results were conducted by covering all the sample details with corrosion-resistant powder coatings. Samples were covered with a powder coating with a thickness of 1.7 to 2.4. These samples were tested sequentially in a special laboratory device, each sample was tested for 25 minutes. The results of this test were repeated 4-5 times for one sample, and 6-7 times for standardized samples. The following tables 2-3 show the results of experimental studies.

Table 2. Abrasive wear of experimental and standard samples.

No.	Steel grade	Test time, min	Wear before the test, g	Wear after the test, g	The difference in test results
#1. Abrasive corrosion of experimental samples before processing.					
1.	20	30	145.5596	145.5566	0.0030
2.	20	30	145.5566	145.5540	0.0026
3.	20	30	145.5540	145.5519	0.0021
4.	20	30	145.5519	145.5503	0.0016
5.	20	30	145.5503	145.5492	0.0011
6.	20	30	145.5492	145.5486	0.0006
7.	20	30	145.5486	145.5484	0.0002
8.	20	30	145.5484	145.5484	0.0000
#2. Abrasive corrosion of experimental samples before processing.					
1.	25	30	145.5892	145.5864	0.0028
2.	25	30	145.5864	145.5841	0.0023
3.	25	30	145.5841	145.5824	0.0017
4.	25	30	145.5824	145.5811	0.0013
5.	25	30	145.5811	145.5803	0.0008
6.	25	30	145.5803	145.5799	0.0004
7.	25	30	145.5799	145.5798	0.0001
8.	25	30	145.5798	145.5798	0.0000
#3. Abrasive corrosion of experimental samples before processing.					
1.	30	30	145.6090	145.6064	0.0026
2.	30	30	145.6064	145.6043	0.0021
3.	30	30	145.6043	145.6027	0.0016
4.	30	30	145.6027	145.6016	0.0011
5.	30	30	145.6016	145.6009	0.0007
6.	30	30	145.6009	145.6006	0.0003
7.	30	30	145.6006	145.6005	0.0001
8.	30	30	145.6005	145.6005	0.0000
#1. As a result of experimental studies, abrasive wear of material with a powder coating thickness of 1.7 mm.					
1.	35GL	30	145.4092	145.4075	0.0017

2.	35GL	30	145.4075	145.4063	0.0012
3.	35GL	30	145.4063	145.4055	0.0008
4.	35GL	30	145.4055	145.4051	0.0004
5.	35GL	30	145.4051	145.4049	0.0002
6.	35GL	30	145.4049	145.4049	0.0000
#2. As a result of experimental studies, abrasive wear of material with a powder coating thickness of 2.4 mm.					
1.	45L	30	145.4088	145.4072	0.0016
2.	45L	30	145.4072	145.4061	0.0011
3.	45L	30	145.4061	145.4053	0.0008
4.	45L	30	145.4053	145.4048	0.0005
5.	45L	30	145.4048	145.4046	0.0002
6.	45L	30	145.4046	145.4046	0.0000
Abrasive wear of standard sample No. 04 made of manganese steel before heat treatment.					
1.	65L	30	145.4085	145.4070	0.0015
2.	65L	30	145.4070	145.4060	0.0010
3.	65L	30	145.4060	145.4053	0.0007
4.	65L	30	145.4053	145.4049	0.0004
5.	65L	30	145.4049	145.4048	0.0001
6.	65L	30	145.4048	145.4048	0.0000

Table 3. Abrasive wear of experimental and standard samples.

No.	Steel grade	Test time, min	Wear before the test, g	Wear after the test, g	The difference in test results
#1. Abrasive corrosion of experimental samples before processing.					
1.	20	30	145.2567	145.2550	0.0017
2.	20	30	145.2550	145.2538	0.0012
3.	20	30	145.2538	145.2530	0.0008
4.	20	30	145.2530	145.2524	0.0006
5.	20	30	145.2524	145.2520	0.0004
6.	20	30	145.2520	145.2518	0.0002
7.	20	30	145.2518	145.2518	0.0000
#2. Abrasive corrosion of experimental samples before processing.					
1.	25	30	145.2768	145.2773	0.0015
2.	25	30	145.2773	145.2761	0.0012
3.	25	30	145.2761	145.2752	0.0009
4.	25	30	145.2752	145.2745	0.0007
5.	25	30	145.2745	145.2740	0.0005
6.	25	30	145.2740	145.2738	0.0002
7.	25	30	145.2738	145.2738	0.0000
#3. Abrasive corrosion of experimental samples before processing.					
1.	30	30	145.2869	145.2855	0.0014
2.	30	30	145.2855	145.2845	0.0010
3.	30	30	145.2845	145.2838	0.0007
4.	30	30	145.2838	145.2833	0.0005
5.	30	30	145.2833	145.2829	0.0004
6.	30	30	145.2829	145.2827	0.0002
7.	30	30	145.2827	145.2827	0.0000
#1. As a result of experimental studies, abrasive wear of material with a powder coating thickness of 1.7 mm.					
1.	35GL	30	145.1018	145.1013	0.0005
2.	35GL	30	145.1013	145.1010	0.0003
3.	35GL	30	145.1010	145.1008	0.0002

4.	35GL	30	145.1008	145.1007	0.0001
5.	35GL	30	145.1007	145.1007	0.0000
#2. As a result of experimental studies, abrasive wear of material with a powder coating thickness of 2.4 mm.					
1.	40GL	30	145.1016	145.1010	0.0006
2.	40GL	30	145.1010	145.1006	0.0004
3.	40GL	30	145.1006	145.1004	0.0002
4.	40GL	30	145.1004	145.1003	0.0001
5.	40GL	30	145.1003	145.1003	0.0000
Abrasive wear of standard sample #. 04 made of manganese steel after heat treatment.					
1.	65G	30	145.1013	145.1004	0.0009
2.	65G	30	145.1004	145.0998	0.0006
3.	65G	30	145.0998	145.0995	0.0003
4.	65G	30	145.0995	145.0994	0.0001
5.	65G	30	145.0994	145.0994	0.0000

No.	Steel grade	Test time, min	Wear before the test, g	Wear after the test, g	The difference in test results
1.	40GL	30	145.1016	145.1010	0.0006
2.	40GL	30	145.1010	145.1006	0.0004
3.	40GL	30	145.1006	145.1004	0.0002
4.	40GL	30	145.1004	145.1003	0.0001
5.	40GL	30	145.1003	145.1003	0.0000
1.	65G	30	145.1013	145.1004	0.0009
2.	65G	30	145.1004	145.0998	0.0006
3.	65G	30	145.0998	145.0995	0.0003
4.	65G	30	145.0995	145.0994	0.0001
5.	65G	30	145.0994	145.0994	0.0000

As can be seen from the results of the research (tables 2-3), we can say that the powder coating on materials with a thickness of 1.7-2.4 mm fully corresponds to the test results for production enterprises. Experimental studies have shown that this condition becomes stronger when it is heat treated twice and three times. This is very important for production enterprises [20-23].

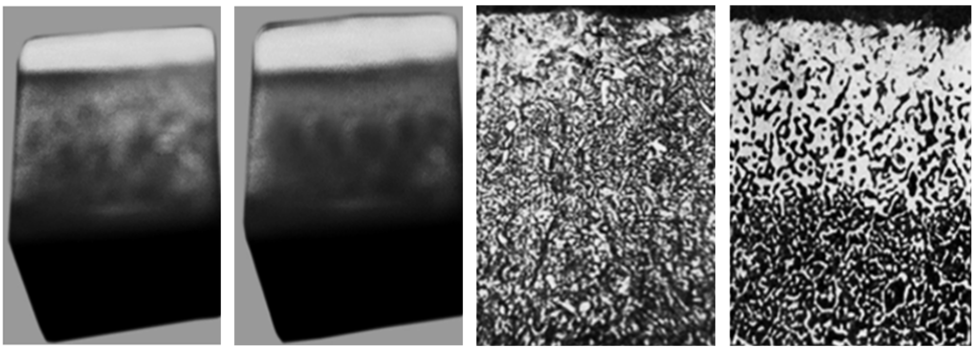
4 Results and discussion

As a result of experimental studies, 18 samples were produced for the experiment. The tests were carried out in three stages. In the results of each test, samples of three different brands of steel were tested. Abrasive corrosion of powder coated steel coatings was continuously monitored. The results of this test were conducted in test fields in different regions of our republic, and these differences were compared according to the results of time trials (Table 4).

Table 4. Comparison difference of research results.

No.	Brands of tested parts	Relative resistance to eating
1.	Steel 70G	1.0
2.	Steel 30G	1.2
3.	Steel 40F	1.5-2.0
4.	Steel 50G	2.5-3.0

Cast hardened and tempered samples and parts having a wear-resistant surfacing with a layer thickness of 2.0-2.5 mm (Fig. 2, a, b) and fine-needle (granular) martensitic structures (Fig. 2, c, d) increase the hardness HRC58-62, microhardness HV1800-2200 and wear resistance by two or more three times.



a b c d

Fig. 2. Cast hardened and tempered samples with a wear-resistant surfacing coating (layer) obtained by casting according to gasified models: a-2.0 mm; b-2.5 mm; c, d-fine-grained martensitic structures with a surface layer (X500).

Abrasive wear is the process of destruction of the surface by cutting and scratching with hard abrasive particles of the medium in which the work of machine parts takes place. The hardness of abrasive particles is higher than that of metal, which contributes to the destruction of the surface of the parts and dramatically increases their wear [20]. Heat treatment of cast samples and parts was carried out in the following modes: the first hardening 940ºC-1150ºC, intermediate tempering 400-650ºC and the second hardening 900-920ºC, tempering 180-200ºC. However, the heating temperature of 900ºC was sufficient for the formation of a martensitic structure in areas with a pearlite component. Pearlite and austenitic components of the structure gradually moved to martensitic structures. The location of the carbide component does not change. The total depth of the surfacing powder coating, which includes both a wear-resistant layer and a high-carbon sublayer, also does not change. The final heat treatment, quenching at 900ºC and tempering at 200ºC, fully ensures the formation of fine-grained martensitic structures.

5 Conclusion

The main process of preventing abrasive corrosion of steel samples is to apply powder coatings to the surface coating of the material during casting. This process is characterized by the optimal coverage of high primary carbides as well as martensite coatings. As a result, it gives the opportunity to increase the operating cycle of these materials up to 15%-20%.

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