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Study of the kinetics of wear of steels from the point of view of the provisions of the adhesive-hydrodynamic theory of wear

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Abstract

The article is devoted to the study of wear resistance of the surface layer of steels 40X and ШХ15, when rubbed in oil I-20. A comparison of the surface layer of samples of raw and nitrided steels, before and after the tests. The study of the fine microstructure of the samples with the help of the LDFP microscope, allowed us to conclude that the samples that were subjected to ionic nitriding, improved roughness. In turn, increased the area of linear contact, reduced contact load. The graphic dependence of roughness indicators is constructed. After testing, we can conclude that nitrided steel has a long service life, namely high hardness, resistance to abrasion, durability and corrosion resistance. The mechanism for obtaining increased resources needs further study.

Key words: test, operation, friction, 40X, ШХ15, ionic nitriding, sample, roughness, I-20

Purpose

Study of the kinetics of wear of steels from the point of view of the provisions of the adhesive-hydrodynamic theory of wear

Introduction

Quantitative comparison of performance characteristics of raw and nitrided steels. The studies were carried out with samples of 40X and ШХ15 steels. Rolling friction tests in I-20 oil were carried out for steels without and after heat treatment. The data are presented in tables.

Table 1

The nature of wear and durability of samples of steel 40X without heat treatment and nitrided, when tested for rolling friction in oil I - 20.

Test time, hour	The number of cycles, $N \cdot 10^6$	Load per ball 150 H			
		Raw steel		Nitrided steel	
		Wear U, μm	Hardness H100, μm	Wear U, μm	Hardness H100, μm
0	0	0	5480	0	7460
10	5.4	5 – 6	5720	4 – 5	7500
25	13.5	–	–	–	–
50	27	10 – 12	–	9 – 12	7460
75	40.5	15 – 20	5550	14 – 19	–
100	54	26 – 30	5520	22 – 25	7280
150	81	–	–	–	–
200	108	40 – 45	5430	30 – 32	7100

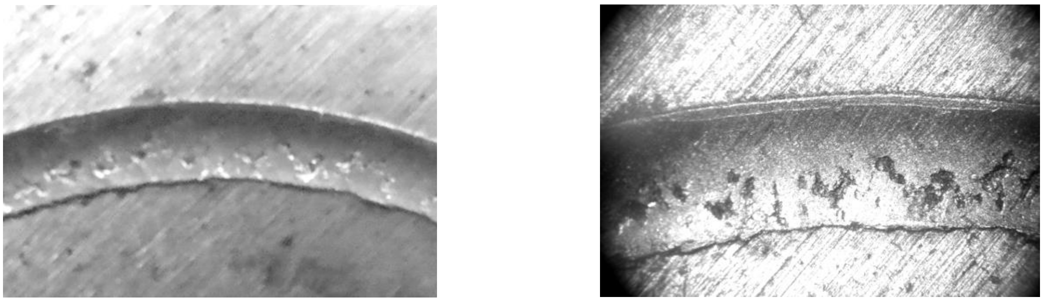
Continuation of Table 1

250	135	–	–	–	–
300	162	55 – 60	5420	58 – 65	6840
350	189	370 hours U = 58–62 μm, N·106 = 199.8, H100= 5520			–
400	216			65 – 70	6550
450	243			–	–
500	270			70 – 75	5850
550	297			–	–
600	324			75 – 80	5400
650	351			–	–
700	378			80–85	4850
				The rest	

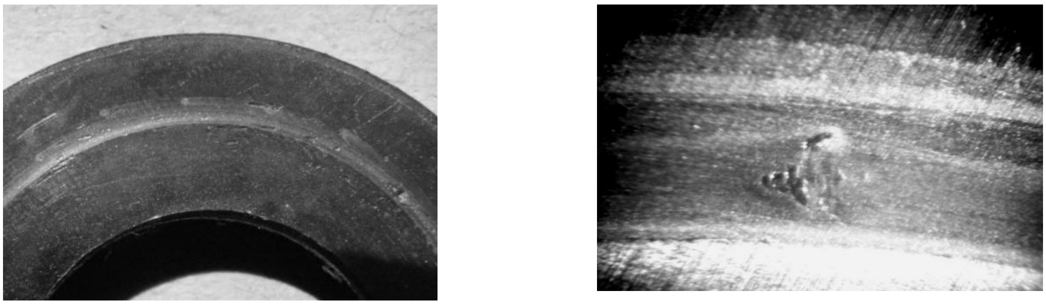
Table 2

Physical, mechanical and tribological characteristics of samples with different coatings and their durability during rolling friction tests in oil I-20.

Sample number	Steel grade	Type of heat treatment	Surface hardness	Load per ball 150 H		
				Test time, min	Wear U, μm	The number of cycles, $N \cdot 10^6$
1	ШХ 15	Without heat treatment	H_{100} 3340	80	46	0.7
2	ШХ 15	Tempered	HRC 60–61	–	–	–
3	ШХ 15	Tempered + nitrided	H_{100}= 5880	60	18	0.54
				Load per ball 300 H		
1	ШХ 15	Without heat treatment	H_{100} 3340	–	–	–
2	ШХ 15	Tempered	HRC 60–61	46	14	25.1
3	ШХ 15	Tempered + nitrided	H_{100}= 5880	34	38	18.4



Friction track of a sample made of 40X steel without heat treatment
12 hours of work



Friction track of a sample made of 40X steel, tempered and nitrided
183 hours of work

Fig. 1. Comparison of the friction paths of 40X steel samples without heat treatment and after nitriding, during friction in I-20 oil.

The studies of rolling friction in oil I-20 made it possible to determine the characteristics of strength, ductility and wear resistance of samples of steels 40X and ШХ15. The studies were carried out on samples without heat treatment, tempered and subjected to ion nitriding. The studies were carried out using a setup for testing contact endurance and wear resistance at linear contact. After the tests, it can be concluded that nitrided steel has a longer service life, namely, high hardness, resistance to seizure, endurance and corrosion resistance.

Study of the fine microstructure of samples using a LDFP microscope

Most carbon non-polar materials, when wetting the surfaces of machine parts, form epitropic liquid crystal structures on them in the nano- and micrometer range. Since their structure and properties are largely determined by the roughness of the working surface, it is necessary to have the most complete information about the three-dimensional state of the original surface. The nano-geometric surface of the samples needs appropriate control, which must be carried out by a non-contact method with high profile sensitivity and a sufficiently large field of view. Contact profilographs-profilometers of the Caliber M201 or M-283 type do not meet these requirements due to surface damage and low information content. Therefore, a laser scanning non-contact differential-phase microscope-profilograph-profilometer (LSDPMP) was used for the study. It was experimentally established that it is the 3D state of the working surfaces that characterizes their tribological properties, and not the roughness parameters (Ra, Rz, Rmax, Sm, tp, etc.), calculated only from the profilogram.

It has been experimentally established that for the same roughness parameter, in particular Ra, created by different technological methods, the surfaces have fundamentally different tribological properties depending on their 3D state.

In addition to roughness, the microscope allows you to determine the volume of worn material in cubic nanometers, which significantly increases the accuracy of determining the amount of wear.

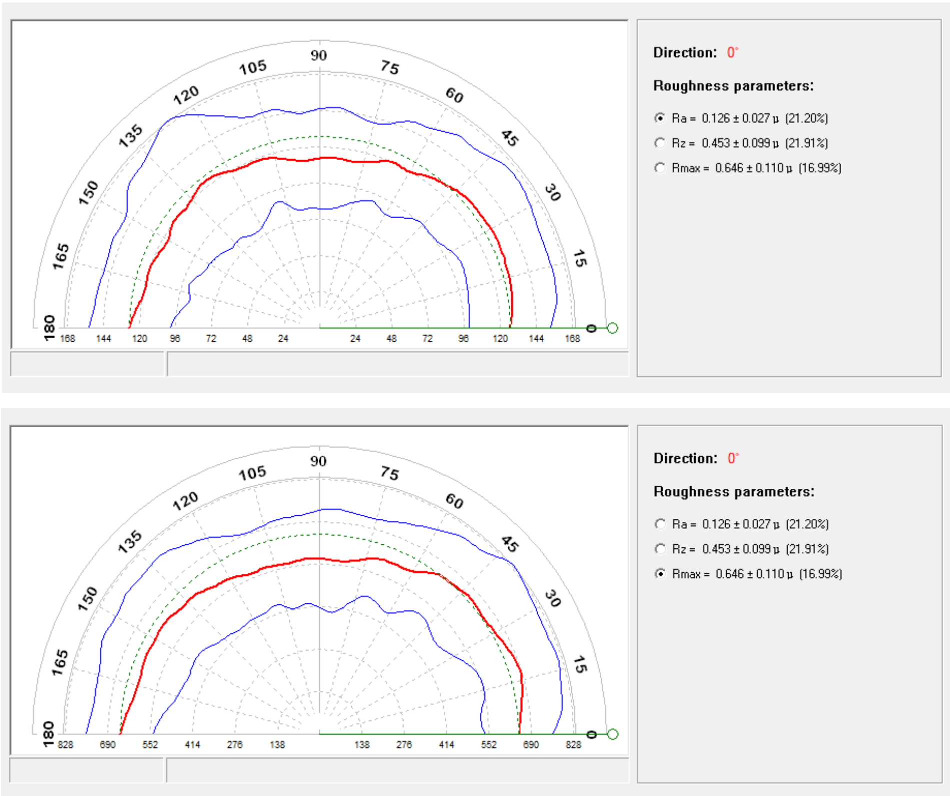


Fig. 2. Graph of displaying the dependence of the values of the roughness parameters on the azimuth angle in the XY plane

On the graph, the red line shows the angular dependence of the average value of the selected roughness parameter, and the blue lines show the boundaries of the deviation of this parameter from its average value within the studied area of the surface.

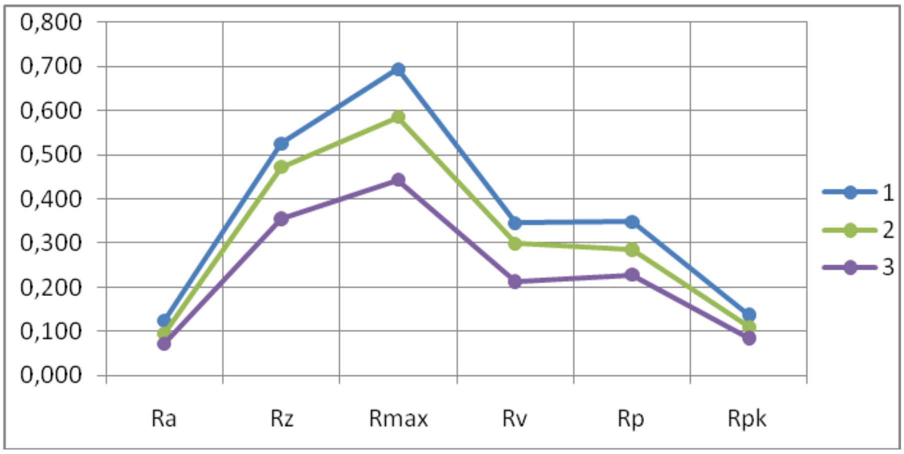
Results

After testing the wear resistance during rolling friction in I-20 oil, the surface of the samples was examined using an LDFP microscope, the results are presented in tables 3, 4.

Table 3

Parameters of the investigated roughness along the raceway.

No	Steel grade	Type of heat treatment	Roughness parameters, microns						
			Ra	Rz	Rmax	Rv	Rp	Rpk	Sm
1	40X	Without heat treatment, raw	0.125	0.525	0.694	0.346	0.348	0.137	48.255
2	40X	Temper + nitrided	0.096	0.472	0.585	0.299	0.286	0.110	25.392
3	ШХ15	Temper + nitrided	0.074	0.356	0.443	0.214	0.229	0.087	27.188



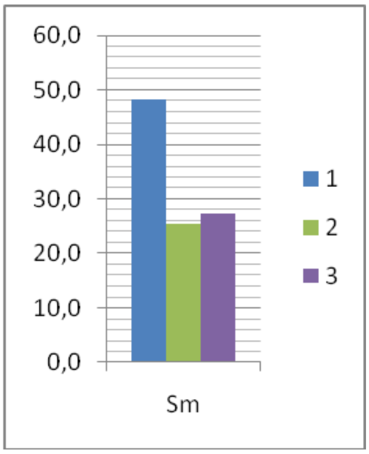
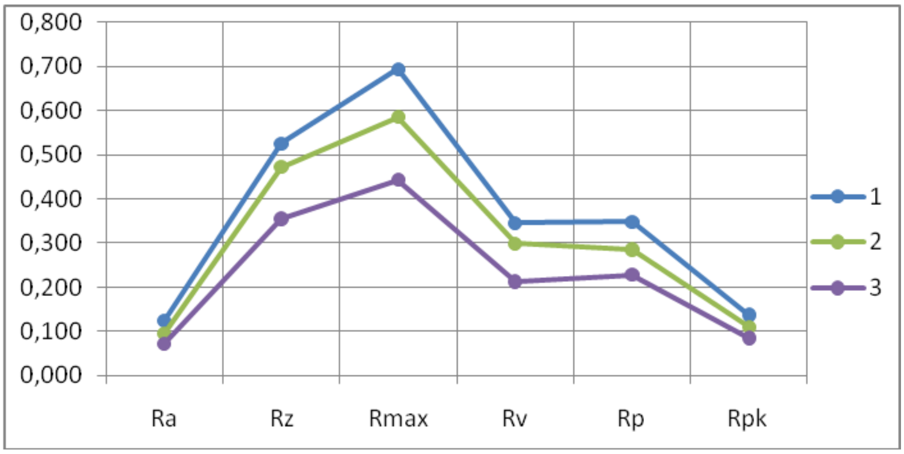
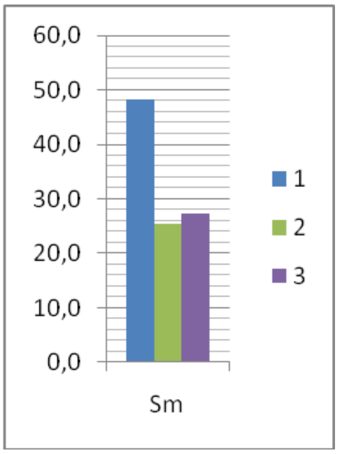


Table 4

Parameters of the investigated roughness along the lateral surface

No	Steel grade	Type of heat treatment	Roughness parameters, microns						
			Ra	Rz	Rmax	Rv	Rp	Rpk	Sm
1	40X	Without heat treatment, raw	0.161	0.652	0.855	0.410	0.445	0.187	48.078
2	40X	Temper + nitrided	0.036	0.177	0.217	0.113	0.103	0.038	27.596
3	ШХ15	Temper + nitrided	0.079	0.360	0.426	0.213	0.213	0.088	33.931





Conclusion

Samples of steel 40X and ШХ-15 were used for the experiment. The experiments carried out confirmed that the surface roughness of the boundary layer after ion nitriding improved, namely, the step of irregularities, the difference between tops and troughs of the relief decreases, the area of irregularities decreases, which in turn leads to an increase in the surface contact area, a decrease in the contact load.

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Побережний М.М. Каплун П.В. Каленов С.О. Дослідження кінетики зношування сталей з точки зору положень адгезійно-гідродинамічної теорії зношування

Стаття присвячена дослідженню зносостійкості поверхневого шару сталей 40Х і ШХ15, при терті кочення в мастилі І-20. Проведено порівняння поверхневого шару зразків сирих та азотованих сталей, до та після випробувань. Проведене дослідження тонкої мікроструктури зразків за допомого мікроскопу ЛДФП, дозволило зробити висновок, що у зразках які були піддані іонному азотуванню, покращились показники шорсткості, що в свою чергу збільшило площу лінійного контакту, зменшилось контактне навантаження. Побудована графічна залежність показників шорсткості. Після проведених випробувань можна зробити висновок що азотована сталь має великий ресурс роботи, а саме велику твердість, стійкість проти спрацювання, краща витривалість та корозостійкість. Виявлено доцільність проведення подальших досліджень з визначення впливу ХТО на механізми зношування поверхонь та шляхів підвищення їх зносостійкості.

Ключові слова: випробування, спрацювання, тертя, 40Х, ШХ15, іонне азотування, зразок, шорсткість, І-20.