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ON INFLUENCING SURFACE HARDENING TECHNOLOGY ON THE NANOGEOMETRY OF THE SURFACE LAYER AND ITS WEAR RESISTANCE

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Abstract

For fine grinding and ion implantation, profilograms of surface nanogeometry are obtained using an atomic force microscope. The parameters of nanogeometry are determined in accordance with ISO 4287. The results of changing the parameters of nanogeometry depending on the type of technological treatment are given. The conducted experimental studies on wear show that the running-in process does not influence significantly the surface nanogeometry. The nanogeometry parameters of the friction surface are given, which are preferable from the viewpoint of reducing wear for the selected test conditions.

Keywords: nanogeometry, technology, surface hardening, engineering technology.

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1. INTRODUCTION

Currently, ever higher requirements are imposed on engineering products. The task is to increase the reliability of products and units of mechanical engineering while reducing or maintaining the cost of manufacturing parts. Along with the traditional methods of ensuring the reliability of units and parts, methods of improving the quality of the surface layer of parts and units based on combined and complex technological methods are becoming increasingly important. These methods make it possible to form a surface layer with the required geometric and physical-mechanical properties and to use such parts in precision friction units.

Based on recent studies, it is established that the operational properties are actively influenced by such a nanogeometric characteristic as subroughness, which is described in [1]. Influencing subroughness on one of the operational properties of parts namely wear resistance is described in detail in [2, 3].

The study is based on work [4], which shows the change in surface subroughness when using the technology which hardens the surface layer; however, this change is not shown for materials with different surface structures. The correlation between subroughness and the phase and structural composition of the surface layer is described in [5]. Some aspects of friction surface nanogeometry control are presented in [6].

A number of works are devoted to forming surface nanogeometry by technological methods of influence. Paper [7] shows the nanorelief formation on the aluminum surface treated in atmospheric pressure discharge plasma. It is shown that vertical structures with characteristic dimensions (with a diameter at the base of 300...500 nm and a height of 50...80 nm) are formed on the surface, while the surface roughness remains at the level of Ra = 10...15 nm (without taking into consideration the influence of reinforcing vertical structures). In [8], the surface nanorelief after various electrochemical treatments is studied. It is known about decreasing the nanoroughness of the polymethyl methacrylate surface by vacuum ultraviolet [9]. Studies shows that vacuum ultraviolet treatment with a wavelength of λ=123.6 nm and an intensity of about 7 mJ/(cm^2·s) makes it possible to quite effectively change the film thickness and subroughness of the polymethyl methacrylate surface.

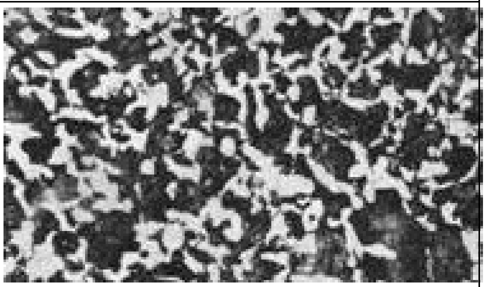
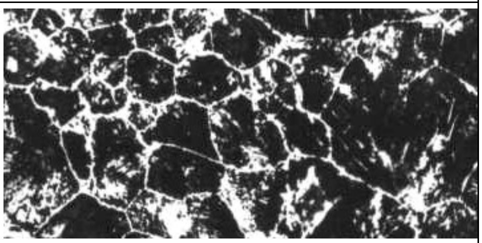
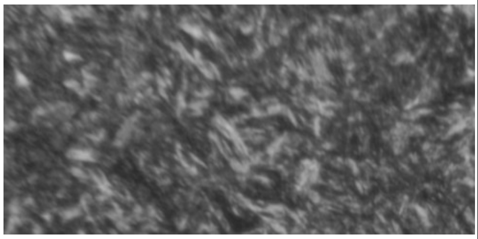
The study of influencing the velocity distribution along the machining tool trajectory shows the possibility of forming the surface nanogeometry by eliminating vibrations when using a curvilinear trajectory of the machining tool [10]. In [11], based on the analysis of subroughness obtained by various methods i.e. edge cutting (planing with a wide cutter) and abrasive machining, which differs in the abrasive trace direction (grinding and lapping), it is concluded that the difference in the directions of machining traces is reflected when determining both microroughness and nanoroughness. The effect of nanoroughness on the structure of a closed vortex flow is studied [12].

The aim of this article is to establish the correlation of surface nanogeometry namely subroughness and technology to improve the surface layer quality.

2. Experimental

The studies are carried out on a batch of samples (Table 1) made of steel 45, heat-treated and subjected to grinding to a roughness of Ra = 1.0 mm.

Table 1. Parameters of the studied samples made of steel 45

Sample, №	Heat treatment	Actual roughness		Actual subroughness		Structure
		Ra, µm	*Sm*, mm	*Ra*$_c$, nm	*Sm*$_c$, nm	
1	-	0,993	0,073	39,16	56,8	
2	hardening 850°C, tempering - 550°C	0,977	0,059	21,65	64,12	
3	hardening - 840 °C, exposure - 230°C for 1 hour, cooling in water	0,970	0,067	4,67	31,45	

The parameters of the actual roughness obtained in the process of grinding and the surface layer structure are given in Table 1. Various modes of heat treatment are chosen to obtain different phase and structural components of the sample surface layer. The structure is determined by metallography using a Leica DM microscope on witness samples.

3. Results and discussion

As it can be seen from Table 1 as a result of grinding, the samples had an actual roughness in the range of Ra = 0.97…1.0 µm; Sm = 0.59…0.73 mm. The surface layer structure of the samples was different: sample 1 had a ferrite-pearlite structure; 2 had an austenitic structure; sample 3 had a martensitic sructure. Measuring the subroughness at the base length l = 0.4 µm on the AFM Femtoscan showed (Fig. 1) that the sample with a ferrite-pearlite structure had subroughness parameters Rac = 39.16 nm, Smc = 56.8 nm, the sample with an austenitic structure had Rac = 21.65 nm, Smc = 64.12 nm, the sample with martensitic structure had Rac = 4.67 nm, Smc = 31.45 nm.

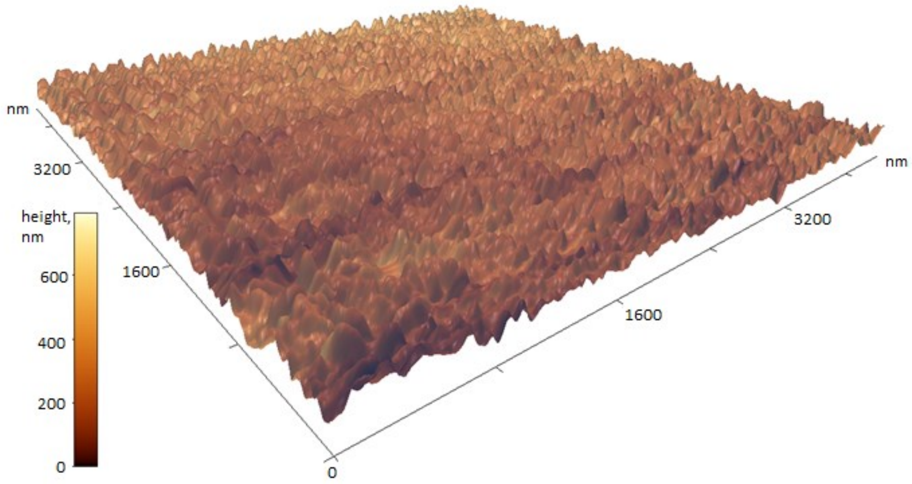


Fig. 1. Sample 1 surface roughness before diffusion siliconizing

The description and procedure for calculating the subroughness parameters are given in [3]. Diffusion siliconizing was used as a technological method for improving the surface layer quality. Diffusion siliconizing is applied to improve the corrosion resistance of machine parts and is not intended to improve wear resistance. However, the processing steps of diffusion siliconizing are suitable for controlling the surface subroughness. Siliconizating was carried out in a chamber in which the temperature was maintained at 230°C. A sample completely covered with powdered silicon carbide was placed in the chamber. The sample was kept in the chamber for 30 min, after which the chamber was opened and the sample cooled in air. Obviously, the temperature regime of diffusion siliconizing will not lead to a change in the phase and structural composition of the surface layer due to using temperatures below the critical points of steel 45 while siliconizing. For this reason, structural studies were not carried out further. Measuring the actual roughness parameters of the samples (Fig. 2, Table 2) made it possible to establish insignificant differences within 17% before and after the technological hardening of the surface layer.

Table 2. Changes in sample geometry parameters

Sample, №	Actual roughness		Actual subroughness	
	Ra, µm	*Sm*, mm	Ra_c, nm	Sm_c, nm
1	0,821	0,044	30,23	29,94
2	0,887	0,040	20,12	34,17
3	0,911	0,047	4,47	12,54

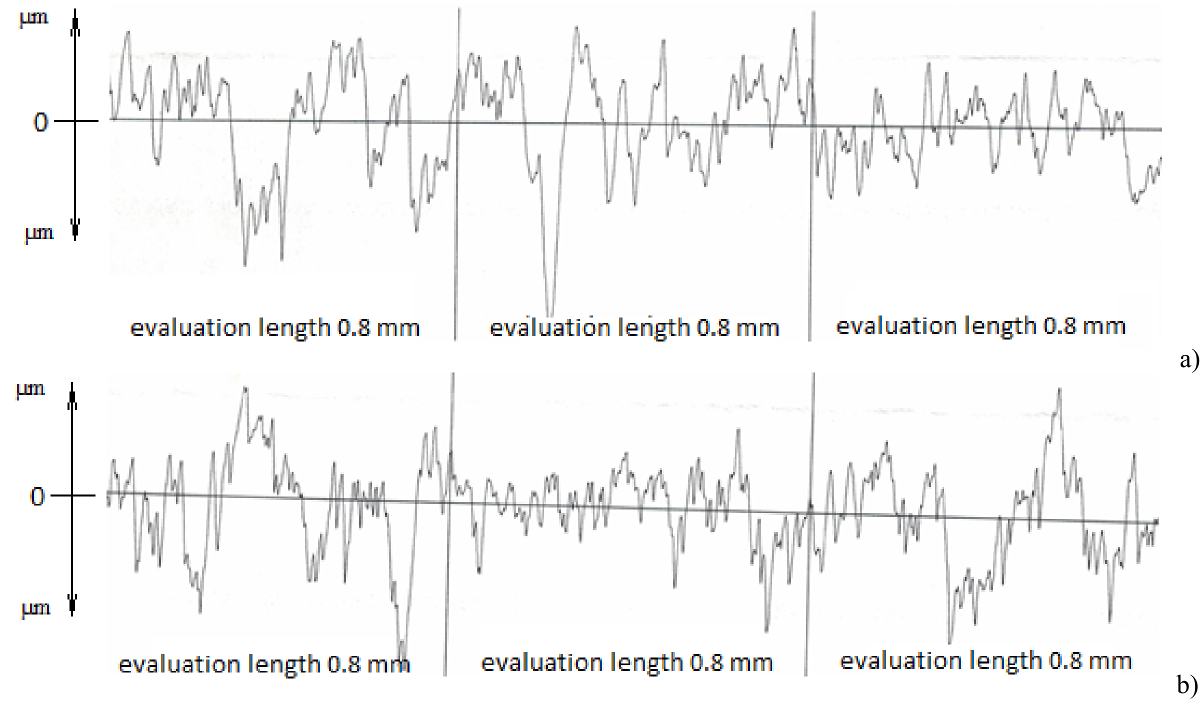


Fig. 2. Sample 1 surface roughness measured at 3 evaluation lengths l = 0.8 mm: a) initial roughness; b) roughness after the surface hardening

Changes in the subroughness parameters of the samples are shown in Fig. 3.

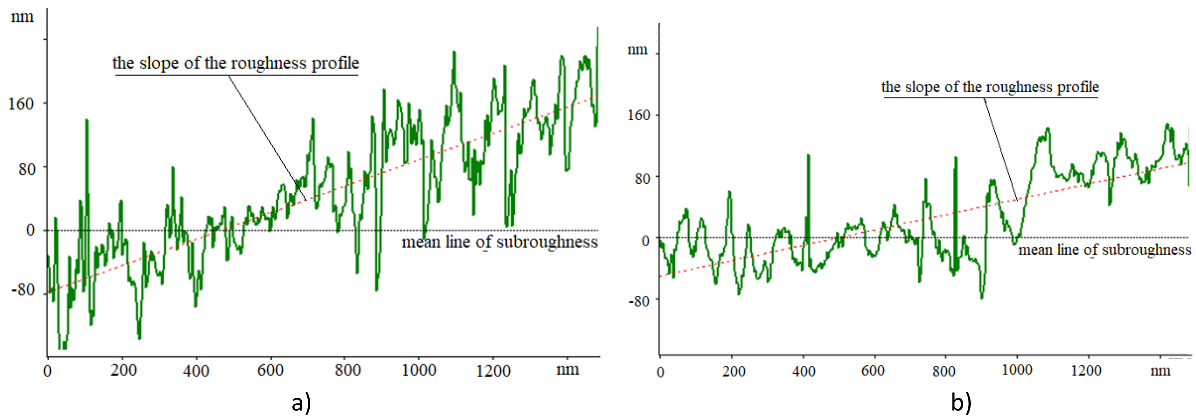


Fig. 3. Sample 1 surface subroughness at the evaluation length l = 0.004 mm: a) initial subroughness; b) subroughness after the surface hardening

4. Conclusions

As a result of the study, it is found that the roughness change does not affect the subroughness change. The values of the subroughness parameters are affected to a greater extent up to 57% by the phase and structural composition of the surface layer [2], by the surface hardening method and by the modes and nanogeometry of the machining tool. Thus, the following findings can be made:

1. Surface nanogeometry can be controlled by technological methods.

2. Surface nanogeometry varies differently with diverse technological methods.

3. The machining trace direction effects indirectly the nanogeometry parameters, due to the machining tool nanogeometry.

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