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SURFACE GEOMETRIC STRUCTURE AFTER VARIOUS TREATMENTS AND WEAR PROCESS

УДК.621

In this study, we analyse the effect of surface treatment on wear process of friction pair components with conformal contact. We discuss characteristics of the outer surface on machine components as well as the relationship between the working surface layers and the method of treatment. We provide results of experiments conducted at a test station designed and built by us. As the measures of wear process, we took mass decrement and the roughness parameter (Ra), which were registered for textures of differing shapes and tool mark positioning. The results we obtained confirmed that the effect of analysed factors on the degree of wear process is significant.

Key words: kind of machining, surface geometric structure, wear process.

1. Introduction

Increased interest in the surface layer of machine components has been observed since research, such as [3, 4, 6], revealed that there is a relationship between the condition of such components' surface layer and their operating characteristics. It has also been confirmed that the wear and tear process – its mechanics, intensity and effects [3, 4, 11, 14] – depends on these operating characteristics, which determine the functional characteristics of the entire engineering structure.

Previous reports in the literature provide many definitions of surface layers. Although these definitions sometimes differ, the essence of the surface layer remains the same or is very similar. In accordance with [2], the surface layer is understood as a set of material particles contained between the actual outer surface of a component and an imaginary surface defined as a boundary of changes in the subsurface area which have occurred due to external forces, such as pressure, temperature, chemical or electrical agents, or bombardment with charged, electrically neutral or other particles. The remaining part of an object's material, which does not belong to the surface layer, is called the core. Whereas the applicable Polish Standard [10] defines surface layer as "a layer of material confined by the actual surface of the object, including this surface and the part of material situated downward from the actual surface with changes in its physical, and sometimes chemical, characteristics as compared to the characteristics of the core material".

Since the outer part of the surface layer is constituted by the surface of elements with a texture defined by surface geometric structure (SGS), it means that the said wear process is also influenced by SGS. The structure is formed of surface irregularities, namely elevations and dents caused by surface treatment or the wear process. These parameters are characteristic for either the process surface layer, that is surface layer technological at the production stage, or the operating surface layer, which occurs during operation.

2. Features surface geometric structure its finish treatment

Stereometric values which define the SGS of components constituting a kinematic pair do indeed describe the operating characteristics of such a pair. These values may be classified and analysed depending on the extent to which they are discussed. In this view, they are then divided into the following sets of parameters [2, 9]:

- macroscopic – lay, waviness, shape deviations;
- microscopic – roughness parameters;
- sub-microscopic – sub-microroughness.

Depending on the positioning of characteristic SGS elements, it may be anisotropic, i.e. to have privileged directions of tool marks, or isotropic – without such directions.

Among the key SGS parameters, which have the biggest influence on tribological characteristics, are surface roughness and lay. The lay has a particular effect on the kinematic pairs with conformal contact between the surfaces of interacting components [3, 4, 11]. The effect of other parameters is less significant for the wear process and its description. Moreover, significance of these parameters is not the same in all conditions of a kinematic pair operation.

The positioning of tool marks is one of the basic factors which determine resistance to relative motion of the interacting components as well as the intensity of wear processes. It is of notable importance where the tool marks are situated relative to each other on both interacting surfaces.

It follows that a thorough and multi-factor analysis is required before one can indicate the best method (in tribological terms) for finishing of kinematic pair component surfaces.

The process technological surface layer can be formed in many different ways, the same as there are many different operations as part of the manufacturing process used for machine components. A very general classification of surface layer production methods, based on material increment, is proposed in studies [2, 12]. According to this classification, surface layer creation methods are divided into:

- decremental – occurring through decrease in the size of an object, e.g. machining, erosion treatment or vapour honing;

- non-decremental – occurring through decrease in the size of an object, e.g. heat treatment, plastic moulding, implantation or PVD;

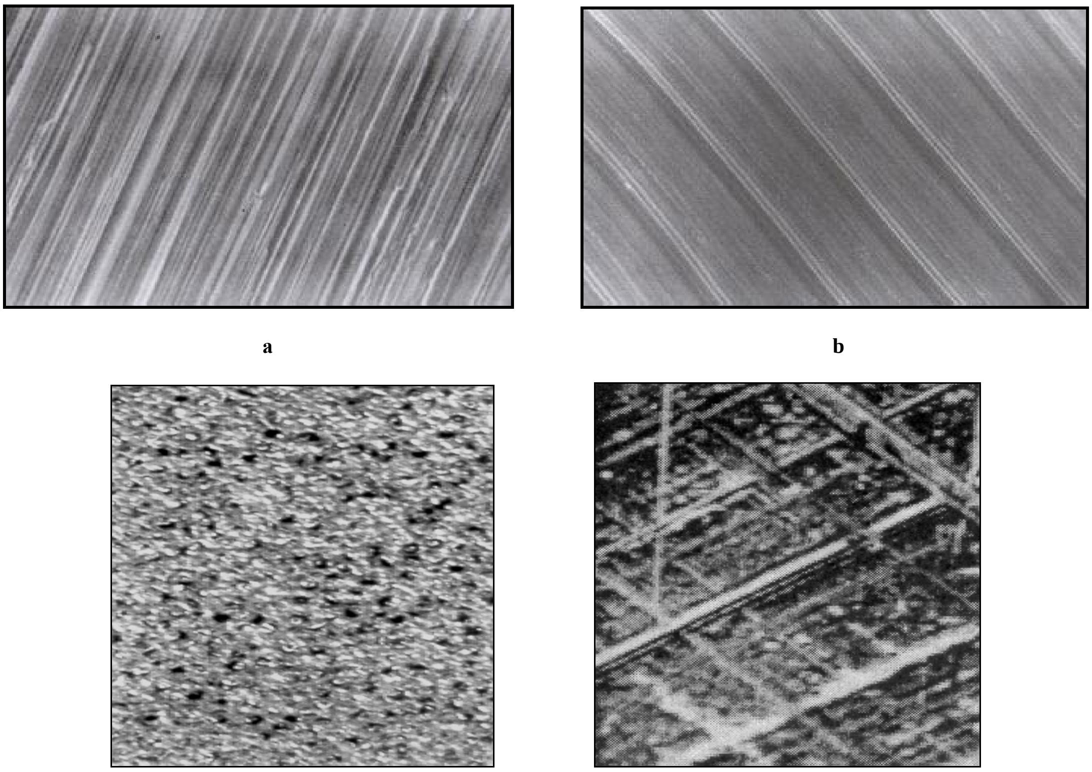
- incremental – occurring through increase in the size of an object, e.g. application of electrolytic coating.

The most popular type are the non-decremental treatments, and among them, due to its versatile character and accurate forming, the machining process based on removal of material allowance layers in the form of chips with the use of the tool point. Machining is estimated to be currently used in approximately 50% of machine-building processes, and according to forecasts by the International Academy for Production Engineering (CIRP) it will continue to be significant for many years to come. It comes as a result of increasing possibilities for the use of machining and higher accuracy [5].

Chip machined surfaces generally have an anisotropic structure, tool marks are directional. It may be mainly described by roughness and lay parameters. Lay obtained by grinding (Fig. 1a) and finish turning (Fig. 1b), that is as a result of basic machining finish, is included in the single-direction group – its marks are parallel to each other [9]. This shape is created by simultaneous effect of independent factors, both random and determined, i.e. tool contour and angles or treatment kinematics (value and relationship between the movements of the tool and the machined object).

Machining is supplemented by erosion treatment in the creation of SGS through material decrement.

In the case of 'clean' erosion treatments, treated surfaces have a random micro-texture (Fig. 1c), revealing high isotropy, and can be mainly characterized by roughness parameters [8, 13]. Roughness level depends on many factors, i.e. discharge current intensity, time of its passage, electrode material properties, the type of dielectric liquid applied etc [1, 8, 13]. Due to minimization of resistance to motion, and consequently friction, as low as possible roughness parameters are sought.



a b

c d

Fig. 1 – Surface stuctures after the following finish treatments:
a – grinding; b – turning;
c – spark erosion; d – electrochemical and abrasive honing

The second parameter to have a key influence on functional characteristics of a created working surface of machine components, namely the lay, occurs in the main only in combined treatments. Surface anisotropy is particularly visible when erosion treatment is combined with mechanical treatments. The most apparent lay of texture is obtained by electrochemical and abrasive machining – ECH + HS (Fig. 1d). The lay obtained on the surface is closely related to the tool kinematics [1].The photographs show clearly that the adopted treatment technology influences the resulting SGS. Beside the adopted treatment method, the obtained surface stereometry is influenced by process parameters. Fig. 2 and Fig. 3 show SGS obtained with various process parameters for electrolytic machining and for hybrid machining, such as milling and turning.

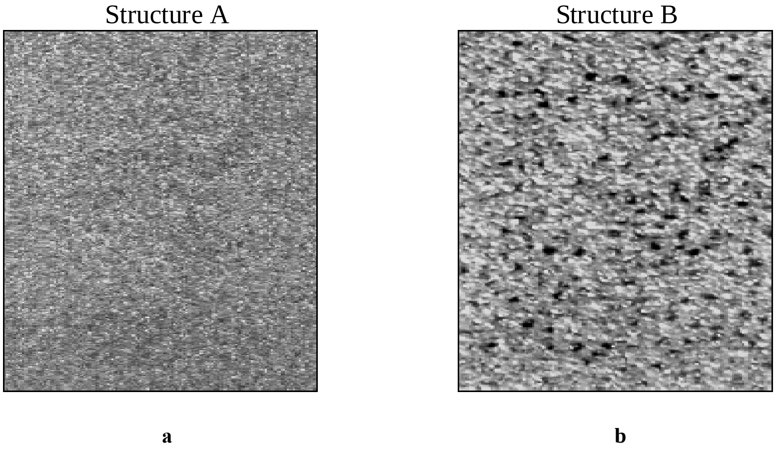


Fig. 2 – Surface structures after spark erosion with various parameters:
a – discharge current intensity of 1 A; discharge time of 3,2 μs; interval of 6,4 μs;
b – discharge current intensity of 6 A; discharge time of 100 μs; interval of 50 μs

Fig. 2 indicates that a change in the basic parameters, such as discharge current intensity, its passage time or impulse interval time, causes a change in the shape and positioning of tool marks on the surface.

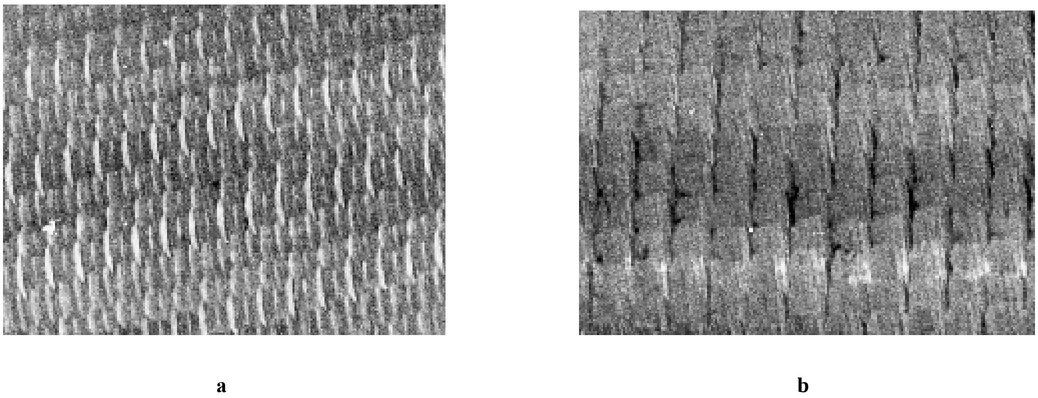


Fig. 3 – Surface structures after milling and turning with various parameters:
a – f_w = 0,75 mm/ rotation;
b – f_w = 2 mm/ rotation

Fig. 3 shows clearly that a change in feed causes a change in the shape and positioning of tool marks on the surface.

3. Analysis of the influence of sgs type, obtained with the use of various treatments on the wear process

3.1. Objective and methods

A properly created surface layer of machine components, occurring as a result of conducted engineering processes, ensures maximum resistance to the effects of wear process, and consequently also a high operational durability of interacting components of a friction pair. A significant element of SGS, as has already been noted, is its roughness and lay, in particular when there is a conformal contact of interacting components of kinematic pairs. Therefore, conducted tests were to determine what is the effect of the positioning and lay of tool marks after various treatments on the intensity of wear process.

The wear process was observed based on samples obtained through grinding, which were anisotropic, (clearly directed tool marks) and had undergone electrolytic machining with isotropic positioning of tool marks. Additionally, in tests on anisotropic textures, relative position of tool marks was changed on samples and the counter sample, with interacting angles taking the following angles resulting from directionality: 0°, 45° and 90°. Whereas tested isotropic textures were characterized by varying positioning of tool marks resulting from different treatment parameters (textures seen Fig. 2). As the measures of the wear and tear process, we used the sample weight decrement (Δm) and the roughness parameter change (Ra), as it is the most frequently used parameter in the industry.

The tests were run on a testing station specially designed and built by the Department of Manufacturing Engineering, University of Technology and Life Sciences, Bydgoszcz [7].

The samples were made of C45 steel, and the counter sample of 100Cr6 steel. In order to ensure that changes in the surface texture occurred predominantly in the surface layer of the samples, the hardness of the counter sample was much higher (by 50 %) than that of the samples – respectively 60 HRC and 40 HRC. The counter sample texture was always anisotropic, its condition was assessed periodically, but no significant traces of any wear process were found.

Samples interacted with the counter sample based on a conformal contact, which, with a load of 450 N, corresponded to a theoretical pressure in the contact area of 1,5 MPa. All of the components were immersed in machine oil, and the relative motion speed in the course of testing was 2,9 m/min (0,05 m/s).

3.2. Experimental test results

Experimental test results are shown as graphs. Fig. 4 depicts changes registered for directional structures obtained through grinding, whereas those in Fig. 5 are for isotropic structures which had undergone electrolytic machining.

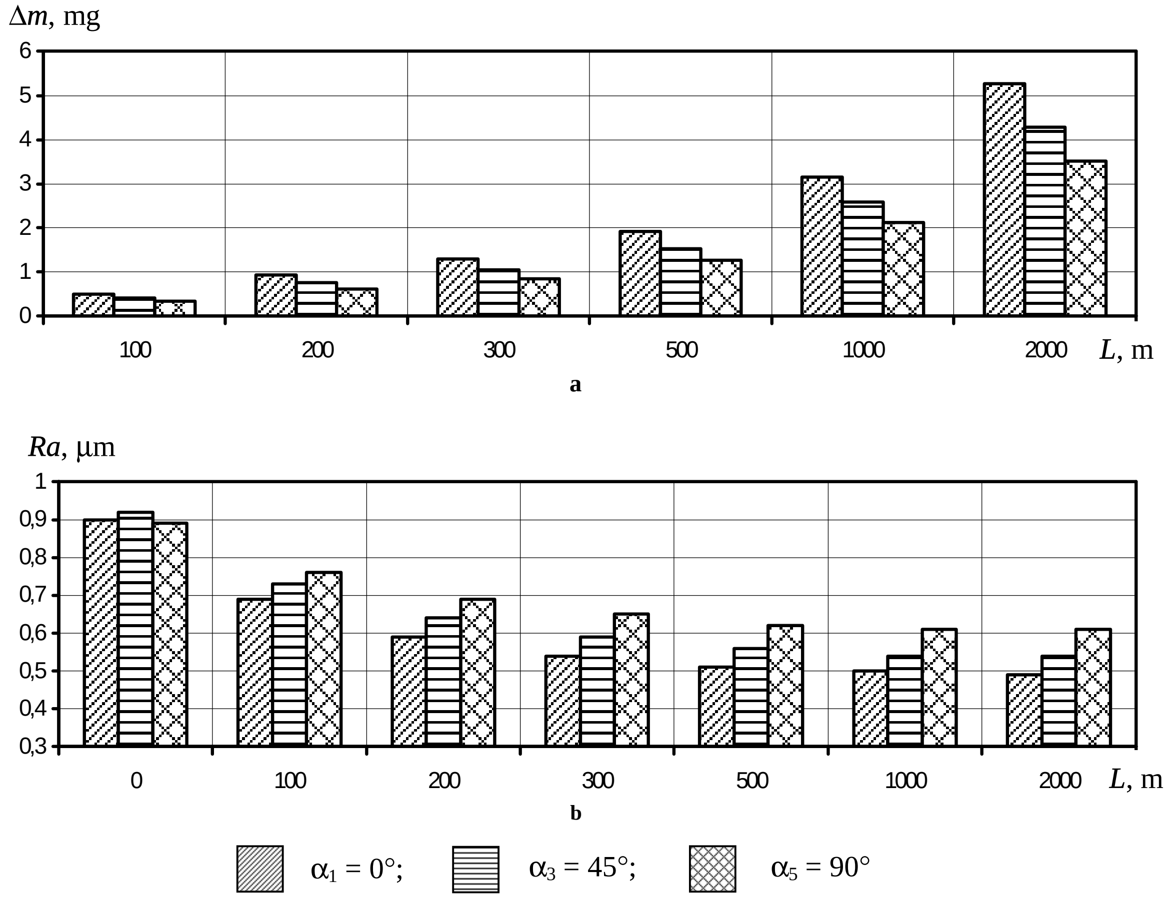
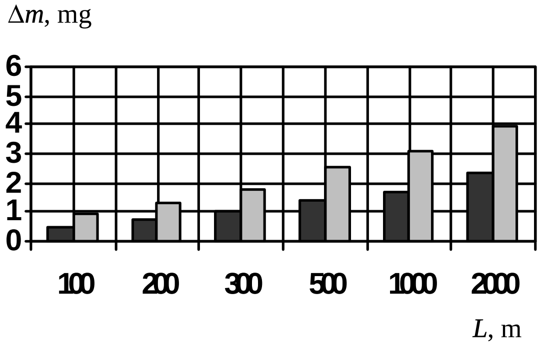
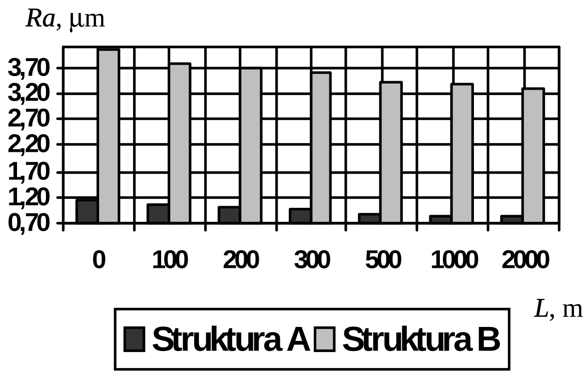


Fig. 4 – Change in the surface layer condition for ground samples as a function of the path of friction, denoted by:
a – weight decrement in tested samples;
b – change in the roughness parameter (*Ra*)

From these graphs one can read the change in the sample weight (Δm – absolute weight decrement as compared to initial sample weight), as a function of the path of friction (L), as well as the change in surface geometric structure, measured by the change in the roughness parameter value (Ra), also a function of the path of friction.



a



b

Fig. 5 – Change in the surface layer condition for samples after EDM treatment as a function of the path of friction, denoted by:
a – weight decrement in tested samples;
b – change in the roughness parameter (*Ra*)

Our tests have demonstrated that changes in the sample weight, which denotes the intensity of wear process, and changes in the roughness parameter (Ra), which denotes changes in SGS, depend on the shape and positioning of tool marks.

Weight decrement shown in the graphs means that in isotropic structures the intensity of wear process is lower as a function of the path of friction than in directional structures. For samples with isotropic structures the wear process along the friction path equalling 2,000 m increased by approximately 4,5 times as compared to the initial level of wear process (along the path of friction equalling 100 m), whereas for anisotropic structures it increased by approximately 10,5 times. What is more, the interacting angle between surfaces resulting from directionality proves to be significant in anisotropic structures. With $\alpha = 0°$, weight decrement is the highest relative to the initial weight, whereas with $\alpha = 90°$, these changes are the smallest.

On charts showing changes in the roughness parameter (Ra), differences are not as significant as in the case of weigh decrement. Changes registered in the value of the roughness parameter for isotropic or anisotropic structures, analysed relatively (to the initial value) were found to be similar. Relative changes fluctuate between 20 % and 45 %. Whereas it was observed that the interaction angle, which results from directionality, influences anisotropic structures. For $\alpha = 0°$, roughness is changed the most as compared to the initial value, and for $\alpha = 90°$, the change is the smallest.

4. Summary

In our experimental tests, we proved that the wear process depends significantly on the characteristics of the surface geometric structure, which is determined by the treatment method.

Due to the fact that the testing was only preliminary, and it confirmed that surface stereometry influences wear process, it is advisable to continue studies and increase number of input factors by including structures with various degrees of isotropy.

Further studies shall make it possible to choose the best treatment method (in tribological terms) depending on the shape and positioning of tool marks, and to obtain in this way the desired surface stereometry.

Thus obtained surface layer characteristics should ensure minimum changes in the surface layer during operation, and at the same time the longest operation with no change in the design characteristics of a friction pair.

Поступила в редакцію 09.01.2013

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