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FEATURES SURFACE GEOMETRIC STRUCTURE OF MACHINE ELEMENTS AND A WEAR RELATED LOSS OF COMPONENT WEIGHT IN A FRICTION PAIR WITH A CONFORMAL CONTACT

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This work analyses the effect of the surface geometric structure directionality on the wear process of elements of friction pairs with a conformal contact. In addition, it describes the characteristics of the surface layer of machine elements with a focus on the importance of directionality of the surface structure in the aspect of the surface layer transformation.

Moreover, this work presents the results of experimental tests where the following input factors were used: tool marks intersection angle on the sample and the counter sample (0°; 30°; 45°; 60° and 90°) and pressure of the sample and the counter sample (1.0; 1.5 and 2.0 MPa). Changes of the surface layer were recorded as a function of a change in the sample weight.

The tests have shown that the intersection angle of tool marks on the sample and the counter sample has a significant effect on the intensity of the wear process. Changes are the greatest for an angle of 0° and the smallest for 90°. In addition, it has been demonstrated that the observed changes have a greater gradient for higher values of sample load, confirming thus the importance of the effect of the surface geometric structure directionality on the wear intensity of the friction pairs elements.

Key words: conformal contact, structure directionality, wear process.

1. Introduction

Durability and reliability of machine interacting elements are inextricably linked with the characteristics of the surface layer as it is this layer that is mainly affected by friction processes that lead to wear and damage. Since the condition of the surface layer has a significant effect on the operating characteristics of machine elements, it is attracts interest from researchers, as well as being the subject of numerous experimental tests. These tests are aimed to acquire and spread the knowledge of the observed surface characteristics and their effect on the tribological characteristics of kinematic pairs. The knowledge obtained from such tests is useful in that it allows the surface layer to be provided with characteristics that increase its resistance to a destructive effect of forces during machine or equipment operation.

The objective of this study was to verify the importance of the surface geometric structure (SGS) directionality for the stages and effects of the working transformation of the surface layer of the friction pair elements with a conformal contact.

2. Features of surface layer and wear process

Features of the surface layer (tension, hardness, structure etc) at various stages of product existence are not constant and are subject to changes. During production, the characteristics of the surface layer (called at this stage the technological surface layer) are dynamic in nature as they practically change following each operation or process activity. These changes relate to both the inner part of the surface layer and its surface, and the entire process is called the transformation of the technological surface layer. However, since the operating characteristics of the kinematic pairs elements are determined by the condition of the surface layer of such components, it is this condition that is assumed as the technological surface layer of a finished item after the last operation as part of a process is finished, and in this aspect it has a static character.

Upon start of operation of an engineering structure, i.e. as soon as the structure and its elements are exposed to external forces, the technological surface layer transforms to the operating surface layer, giving a rise to the transformation process which is a dynamic one, as in the case of the technological surface layer transformation. The common feature of the technological and operating surface layer transformation is therefore the dynamic character of this phenomenon. In the case of the technological surface layer (because operations are performed in stages), an important condition is that occurring at the end of the production stage, whereas the condition important for the operating surface layer is the current one [1].

Features of the surface layer are largely determined by the surface stereometry. The surface stereometry is defined as the surface geometric structure (SGS). It is a collection of surface micro-unevenness, i.e. tool marks or the effects of the wear process. The basic characteristics that describe SGS include: roughness, waviness, anisotropy degree – tool marks directionality, shape deviations and surface defects [2].

Tribological characteristics of the interfacing surfaces of machine elements are determined mostly by roughness and directionality parameters of SGS [3, 4, 5, 8].

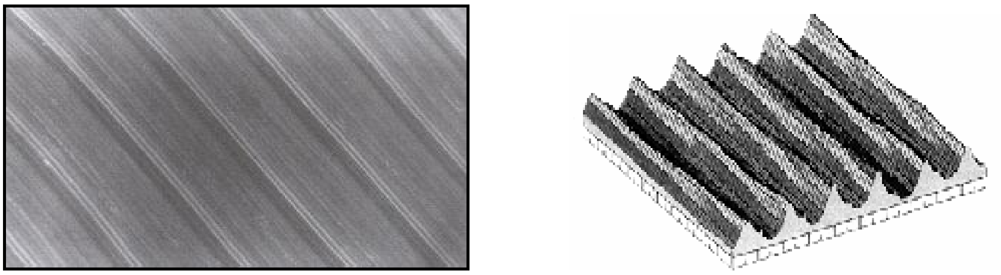
The condition and changes in the surface layer are usually described by various roughness parameters e.g. [8, 9]. Less frequent here is the use of the SGS directionality parameters. Tool marks are an inevitable result of the manufacturing process; they may have a number of different dimensions, shapes and locations so they are significant characteristics of the surface layer condition. It can be therefore stated that a significant component of the SGS from the perspective of the wear process is its directionality. This refers in particular to kinematic pairs with a conformal contact of the interacting surfaces of kinematic pairs elements [5].

3. Experimental tests

3.1. Objective and methodology of tests

The tests were aimed to determine the effect of positioning and directionality of tool marks located on the interacting elements at the conformal contact on the wear intensity. The intensity of the surface layer transformation process was measured based on the weight change (loss), i.e. the value that is used as a direct measure of wear (weight wear).

Tested were the samples of which SGS has an anisotropic character with a clear directionality of tool marks (Fig. 1). The wear stages were observed by changing relative location of tool marks, thus obtaining the structure interacting angle arising from the characteristic directionality lines.



a b

Fig. 1 – Surfacegeometric structure of tested samples:
a – 2D system; b – 3D system

Samples with such surface geometric structure were subjected to tribological tests. Samples made of 102Cr6 steel and a counter sample made of X210Cr12 steel were used in these tests. The samples interacted with the counter sample on the wear test station designed and made at the Manufacturing Engineering Department of the University of Technology and Life Sciences in Bydgoszcz [6, 7].

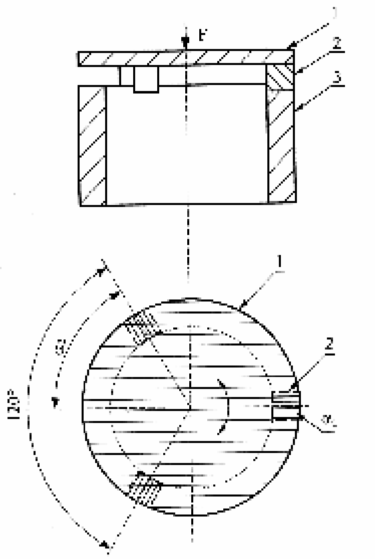


Fig. 2 – Selection of the samples and the counter sample depending on a angle ($a_1 = 0°$ and $a_2 = 60°$) of tool marks intersection:
1– samples; 2 – counter sample; 3 – sample setting sleeve

The hardness of the counter sample was significantly higher (by 50 %) compared to the hardness of the sample so that changes occur mainly on the surfaces of the samples. The value of hardness was respectively 60 HRC and 40 HRC.

The samples interacted with the counter sample in a lubricating medium, that is machine oil (L–AN 68), at the following operating values:

- relative motion speed: 2.9 m/min (0.05 m/s);
- load: 300, 450 and 600 N (which corresponded to theoretical pressure in the contact area of 1.0, 1.5 and 2.0 MPa respectively).

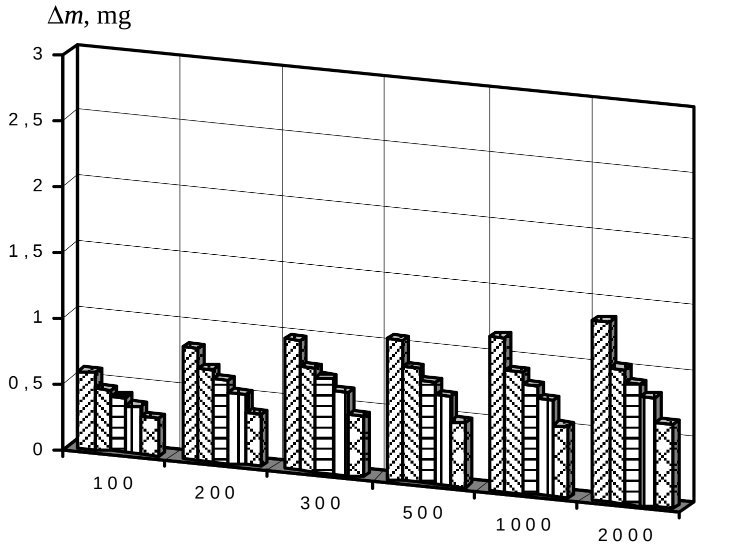
The tests were performed for the following angles between the characteristic tool marks: 0°, 30°, 45°, 60° and 90°.

The principle of selecting the samples and the counter sample during tests and resulting angles between the directionality of the interacting textures during tests are presented in Fig. 2.

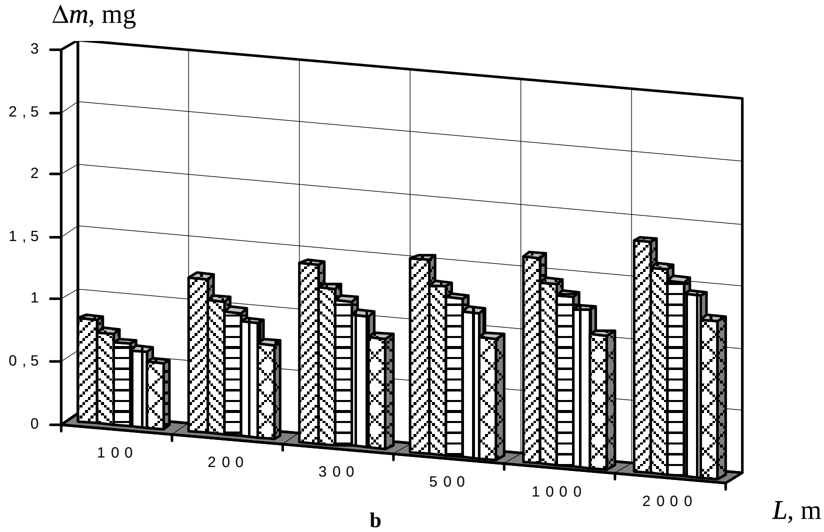
Tested samples were immobilised in three grooves located on the setting sleeve positioned on the circumference at every 120°. Oscillating relative motion was performed by the counter sample, while the counter sample was pressed to the samples (load applied to the system) with springs.

3.2. Results of the experimental tests

The results of the experimental tests are shown in the form of diagrams – Fig. 3 where weight changes of the samples caused by the SGS changes are presented as a function of the friction path. Changes in the weight of the samples were determined during tests by weighing the samples using a WAX 220 analytical laboratory balance with an accuracy to 0.01 milligram.



a



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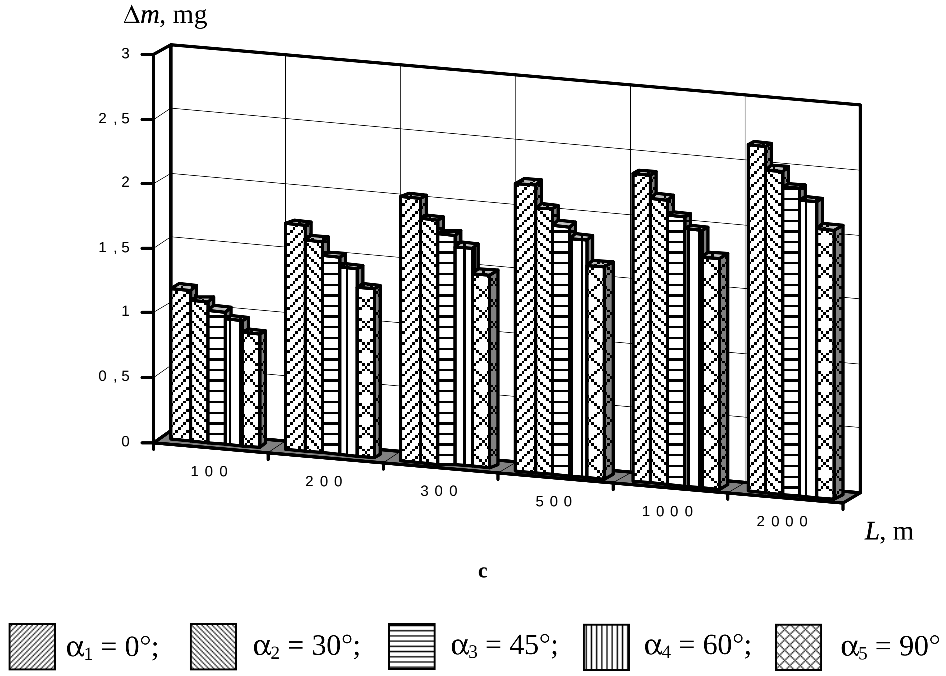

Fig. 3 – Changes in the weight of the samples Dm as a function of the friction path for the following pressure forces: a – 300 N; b – 450 N; c – 600 N

The tests indicate that the changes in the samples weight, i.e. the parameter that describes the intensity of wear process, are dependent on the angles of the characteristic tool marks located on the surfaces of the interacting elements.

The diagrams show that the largest weight loss compared to the initial weight occurs for $\alpha = 0°$, whereas the changes are smaller for $\alpha = 90°$. On the other hand, changes in weights for intermediate angles, i.e. 30°, 45° and 60° are always within these values for angles 0° and 90°. The principle behind these changes is that the weight decreases as the angle increases. This can be explained by the fact that at an angle 0° (parallel marks), micro-unevenness come into contact with each other resulting in the largest loss of material as a result of friction and shearing. At an angle of 90° (perpendicular marks), interfacing surfaces move on the tops of the tool marks causing a smaller loss of material.

Changes of such nature are observed for all interacting conditions (different loads) with the changes in the values within the respective stages of the wear process being more intensive for larger loads. Based on that, it can be stated that, along with verification of the basic assumption of the tests, that is proving that the surface structure directionality has an effect on the surface layer transformation, it was demonstrated that the wear intensity is dependent on the analysed elements interaction conditions.

4. Summary

Based on the experimental tests, it was demonstrated that the wear process depends largely on the surface structure directionality, i.e. on the degree of the structure anisotropy. It was furthermore demonstrated that the intensity of the wear process is dependent on the conditions of interaction between respective elements.

As the effect of the surface stereometry (described by the directionality parameters) on the stages and effects of transformation of the operating surface layer has been proved, it is advisable to continue studies and extend collections of input factors by structures with a various degree of anisotropy.

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

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