Musiał J.
University of Technology and Life Sciences
Mechanical Engineering Faculty,
Bydgoszcz, Poland

SOME SURFACE GEOMETRIC STRUCTURE PARAMETERS CHANGES GENERATED OPERATIONAL EXTERNAL LOADS

1. Introduction

The machine elements surface layer is a factor which largely determines their properties and combination of surface layers of two cooperating elements determines properties of the kinematic pair formed by these elements. One of characteristic element for the surface layer is its geometric structure which determines the process of wear [2].

Extending knowledge on profiling the surface geometric structure (SGS), elaboration and application of new ways for its assessment (qualitative and quantitative) has been possible, thanks to the precise and computer aided measuring equipment. New programming possibilities of the surface analysis in a spatial system (3D) which , in combination with improved precision of measuring tools, allows observation and measurement of SGS elements in a nanometric scale, as well as for its description by means of numerous parameters, not only areal, but also volumetric, spatial, hybrid and functional ones, and with the use of characteristics in the form of curves. The most popular example is the Abbot-Firestone's chart, called a bearing curve. Parameters of the curve one accepted as a measures of the investigated surface changes.

2. Object and method of investigations

In presented investigations bicycle ball bearing was accepted as an object of research. This type of bearing was selected due to its structural form and the resultant kinematics of its elements, big intensity of phenomena accompanying transformation of the surface geometric structure which improves the observation conditions [1].

During test stress values σ_{ψ} = 200 MPa, 621 MPa, 887 MPa, 1381 MPa, 1520 MPa were accepted. Such values demonstrate changes on the whole diameter of the ring.

The tests results were registered for three time values τ – Fig. 1:

- at the beginning of the investigations (beginning of period I), for τ_1 = 0 s – point A;
- in the period of a steady intensity of changes (in the middle of period II), $\tau_2 = 2{,}1 \cdot 10^5$ s – point B;
- at the end of the bearing life (period III), $\tau_3 = 3{,}9 \cdot 10^5$ s – point C.

Measuring points with the above coordinates were accepted on the basis of results of overall research such kind of bearings, contained in works[7].

In Figure 1, a typical wear process has been presented. Three periods can be easily seen in them.

I – fast increase of wear intensity,
II – steady level or slight wear changes ,
III – fast increase in wear intensity.

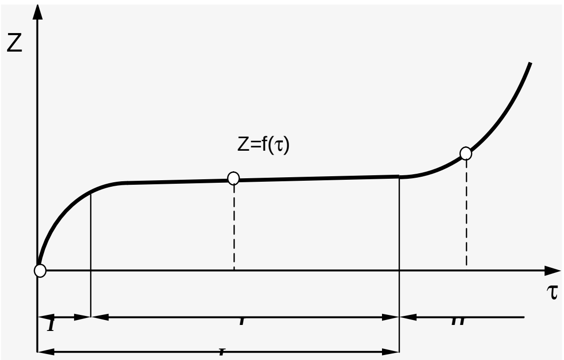


Fig. 1 – Graphic record of a typical wear process

According to a traditional approach it is accepted that the life is a sum of period I and II. On the basis of investigations [7], it was found that with the life criterion in the form of the motion resistance level, a part of period III can also be considered as the period determining the usability boundary, that is the bearing life. Therefore, in this period the third point was also accepted, in which changes were registered.

Parameters of the bearing curve were accepted as parameters defining properties of the examined surfaces. The curve, called Abbot –Firestone's chart, describes the material distribution in the profile. Since the bearing curve provides information on the profile course, in a precise form, it is possible to read from it the profile properties, significant for surface function [4]. Parameters characterizing the bearing curve of roughness profile are:[3, 5, 6]:

Sk – height of the core roughness, μm;

Spk – reduced height of roughness profile elevation, μm;

Svk – reduced depth of roughness profile hollow, μm;

*Sr*1 – bearing share of peaks, %;

*Sr*2 – bearing share of hollows, %;

A – the core area;

*A*1 – area of elevations filled with the material;

*A*2 – area of hollows free from the material.

Graphic interpretation of mentioned above parameters is presented in Figure 2.

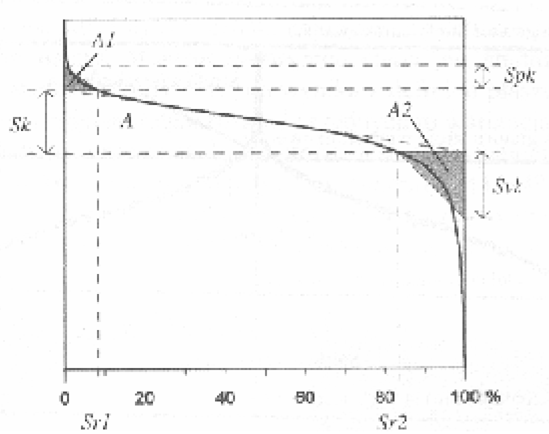


Fig. 2 – Characteristics of bearing curve [5]

Parameter *Spk* can serve as a measurement of effective roughness depth. Value of parameter *Spk* reflects the surface abrasion resistance – it is smaller for bigger resistance. Parameter *Svk* is a measurement of the cooperating surfaces capability to maintain the fluid, therefore, the aim of finish machining is to obtain its possibly high value.

3. Investigation results

Commonly used amplitude parameters do not fully define properties of the examined surfaces, so for this purpose the surface characteristics in the form of bearing curves, were used to extend the evaluation.

In Tables 1, 2 and 3, determined values of the bearing curve parameters are compared for three times, in which the effects of changes in SGS were observed, depending on the stress amplitude σ_ψ.

Tabela 1

Parameters characteristic for bearing curves for $t_1 = 0$ s

Parameters \ Stresses	σ_ψ, MPa				
	200	621	887	1381	1520
Sk, μm	2,26				
Spk, μm	1,05				
Svk, μm	1,38				
*Sr*1, %	9,30				
*Sr*2, %	88,80				

In the first transformation period (from τ_1 to τ_2), parameters *Sk*, *Spk* decreased by about 40 %, whereas, parameter *Svk* underwent minor changes – it decreased in the range from 11,6 % to 24,6 %. This proves that in result of the balls rolling over the raceway there occurred lowering of peaks in the direction to the roughness core. Further operation – until τ_3 time, caused significant changes (increase) of parameters: *Spk* and *Svk* by 10 times, and *Sk* even by 20 times. The cause of such a situation is an increase in the wear process intensity in the form of all kinds of surface damages(craters, cracks, grooves, etc.).

Tabela 2

Characteristic parameters of bearing curves for $\tau_2 = 2{,}1 \times 10^5$ s

Parameters \ Stresses	σ_ψ, MPa				
	200	621	887	1381	1520
Sk, μm	0,23	1,26	1,27	1,31	1,34
Spk, μm	0,28	0,58	0,58	0,58	0,60
Svk, μm	0,10	1,04	1,09	1,14	1,22
*Sr*1, %	9,80	9,30	9,20	9,10	8,90
*Sr*2, %	88,90	90,00	89,50	88,70	88,20

Comparing parameters of the bearing curve in the function of stresses, presented in Table 2, it was found that along with the stresses increase, values of all parameters increased, as well. For minor changes σ_ψ ‹200; 621›, the increase was a few times higher, and then slight. The only parameters whose value in the whole stress changeability range σ_ψ changed to a small degree, were material shares – *Sr*l and *Sr*2. A slight increase in the value of parameter *Sr*1 along with time proves grinding in of the observed surfaces of working bearings under the influence of turning elements rolling on them, whereas slight changes of *Sr2* parameters met the expectations as the action of external loads at the micro-unevenness base should be insignificant.

In Table 3 have been presented dependencies of parameters accepted for the surface geometric structure on stresses, for the third period of use.

The character of changes is similar as for time τ_2 for the smallest stresses, simultaneously great in crease of the examined parameters values was found.

Tabela 3

Characteristic parameters of bearing curves for τ_3 =3,9x 10^5 s

Parameters \ Stresses	σ_ψ, MPa				
	200	621	887	1381	1520
Sk, µm	0,29	19,30	22,40	25,78	28,80
Spk, µm	0,13	5,70	5,90	6,41	6,50
Svk, µm	0,28	10,70	10,94	11,15	11,30
*Sr*1, %	9,60	9,60	9,60	9,80	9,80
*Sr*2, %	88,00	90,20	89,40	88,90	89,00

On the basis of the results contained in Tables 1, 2, 3 it can be found that the raceways of rolling bearings in period II are characterized by the best features of bearing surfaces. A big difference between values *Sr*1 and *Sr*2 and a small value of *Sk* prove that the roughness profile is of the plateau surface type character. Surface of this type is featured by high bearing capacity, small friction and abrasion resistance, that is features highly desired for working surfaces of turning bearings. These observations are confirmed by the expected stabilized intensity of the surface wear process in this period.

4. Mathematical models

In the aim of determinations the relationships between roughness parameters of raceway's on the inner ring and amplitude of pressure, the regress equations in assumed form were estimated.

$Sk = 1{,}3095 - 0{,}0001\cdot\tau + 0{,}0092\cdot\sigma + 2{,}7\cdot10\text{-}10\cdot\tau^2 + 4{,}7\cdot10^{-8}\cdot\tau\cdot\sigma - 6{,}95\cdot10^{-6}\cdot\sigma^2$

$Spk = 0{,}2651 - 2{,}6425\cdot10^{-5}\cdot\tau + 0{,}0038\cdot\sigma + 6{,}9158\cdot10^{-11}\cdot\tau^2 + 1{,}0194\cdot10^{-8}\cdot\tau\cdot\sigma - 2{,}4971\cdot10^{-6}\cdot\sigma^2$

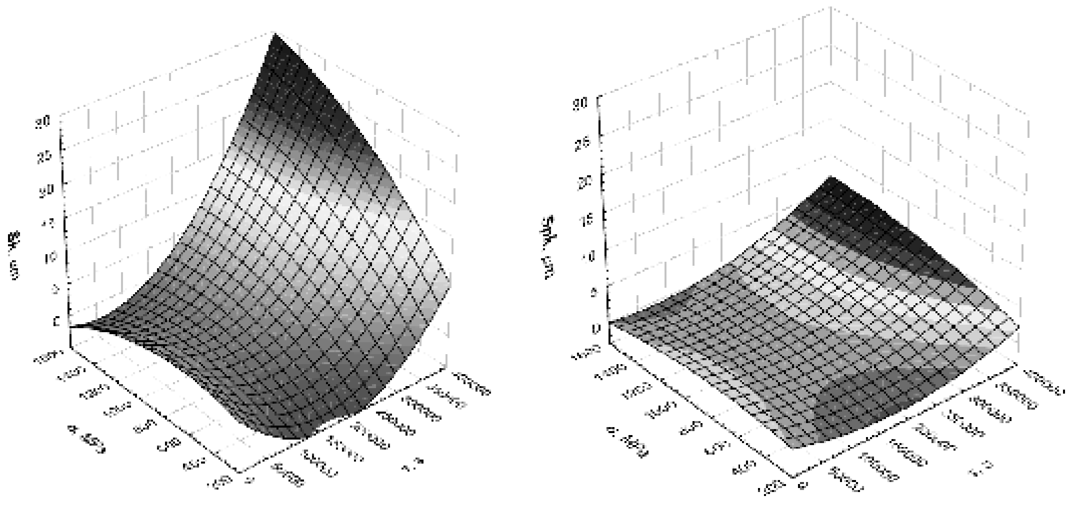
$Svk = -\,0{,}5249 - 4{,}2986\cdot10^{-5}\cdot\tau + 0{,}008\cdot\sigma + 1{,}1897\cdot10^{-10}\cdot\tau^2 + 1{,}7142\cdot10^{-8}\cdot\tau\cdot\sigma - 5{,}0768\cdot10^{-6}\cdot\sigma^2$

$Sr1 = 9{,}6057 - 1{,}8904\cdot10^{-5}\cdot\tau - 0{,}0006\cdot\sigma + 6{,}4713\cdot10^{-12}\cdot\tau^2 + 3{,}6986\cdot10^{-10}\cdot\tau\cdot\sigma + 2{,}0959\cdot10^{-7}\cdot\sigma^2$

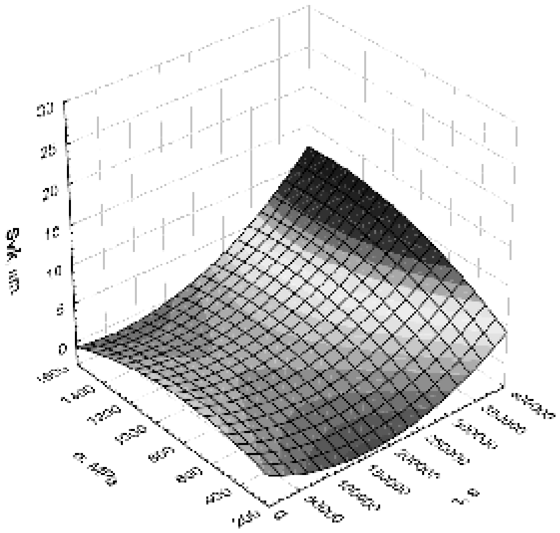
$Sr2 = 87{,}9825 + 1{,}2878\cdot10^{-6}\cdot\tau + 0{,}0032\cdot\sigma - 2{,}6048\cdot10^{-12}\cdot\tau^2 + 5{,}395\cdot10^{-10}\cdot\tau\cdot\sigma - 1{,}9636\cdot10^{-6}\cdot\sigma^2$

The calculated values of coefficients of correlation R are near to 1,0, and the values of coefficient F/F_{tab} are great, so it seems that determined models for all observed parameters are significance and adequate.

In presented below figures graphic form of obtained model for some parameters were shown.



a b



c

Fig. 3. Spatial (3D) graphs of relations between some SGS parameters:
***Sk* (a), *Spk* (b), *Svk* (c), and operating conditions: σ_ψ and τ**

In Fig. 3 essential influence of tested parameters were visible.

4. Summary

Dependencies of parameters describing SGP, that is, characteristics of the bearing curves and stresses in the points of turning elements contact with the race ways, on the internal elements, generated by the bearing external loads, facilitate the choice of the surface layer properties, for which it will be characterized by the expected usability features. These characteristics depend on the kind of finish machining and its parameters, being familiar with these dependencies should make easier its choice, which is of great importance for the final effect of machining.

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