THE AUTOMATION OF PARAMETERS IDENTIFICATION PROCESS FOR PROFILES WITH FUNCTIONAL PROPERTIES

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***Abstract**: The paper presents a way of software construction for calculation the roughness parameters of surface having stratified functional properties. This software is created for using transition model to describe data becomes from the bearing area curve plotted on normal probability paper and is supported by ISO 13565-3, which describes a way of characterization independent components of two-process surfaces.*

***Keywords**: transition model, two-process surfaces, roughness parameters .*

***ACM Classification Keywords**: Algorithms, Measurement.*

Introduction

The geometrical structure of surfaces (GSS) which collaborates with machine parts are being influenced by friction, lubrication and wear, therefore lubricated and sliding surfaces are made as surfaces having stratified functional properties which are named two-process surfaces. These surfaces are the most critical and tribological structure of surfaces. The most often, they are created by putting up several technological processes. They are characterized by occurrence deep valleys on precisely machined top surface layer. Top part of surface, usually smooth is bearing surface and its main goal is to reduce wear, but parts of valleys aim at oil storage and is a trap on small pieces of wear. Plateau honed cylinder surface is the typical example. The topography of this surface is an effect of two processes: base honing and plateau honing.

The precise description of manufactured 2-process surface is a vital problem from practical point of view. There are a lot of methods of two-process surface topography description. One of the alternative approach is to model the surface into two parts, one representing the plateau and the other representing the valley. This becomes possible if the bearing area curve is plotted on normal probability paper. The x-axis of the probability plot is a linear scale of standard deviations and y-axis represents profile height in micrometers [Sannareddy, Raja, Chen, 1998]. If the data from a normal distribution is plotted on a probability paper, then all the data point will fall along a straight line (fig. 1a1). Slope of this line is interpreted as Rq value [Sannareddy, Raja, Chen, 1998]. As Fig. 1.a1 shows, the profile illustrates GSS after base honing (high peaks, and deep valleys), its image at Fig 1.a3 is a large slop line which is equal to big value parameter Rq. The second profile (Fig. 1.b1 – permanent line) describes parts of structure remained before last process which image is less slope line, which corresponds to low value of parameter Rq. Only the last profile (Fig. 1.c1) is measured. In this profile only the dippiest valley the base roughness surface occur, which corresponds to the bottom part of more slope line (Fig. 1.c3). The bottom part of origin roughness profile is removed and replaced by less roughness structure of surface (which is called - plateau), which corresponds to the bottom part of less slope line (Fig. 1.c3). The intersection point on normal probability graph of abscissa Rmq defines the separation of plateau and base textures and is an important feature of the model. The proposed plateau roughness Rpq, valley roughness Rvq and Rmq are three parameters characterising plateau honed surface. Those parameters seem to be of great importance because they are connected with honing process parameters. Therefore automation of determination those parameters have important influence on control a process creating those surfaces.

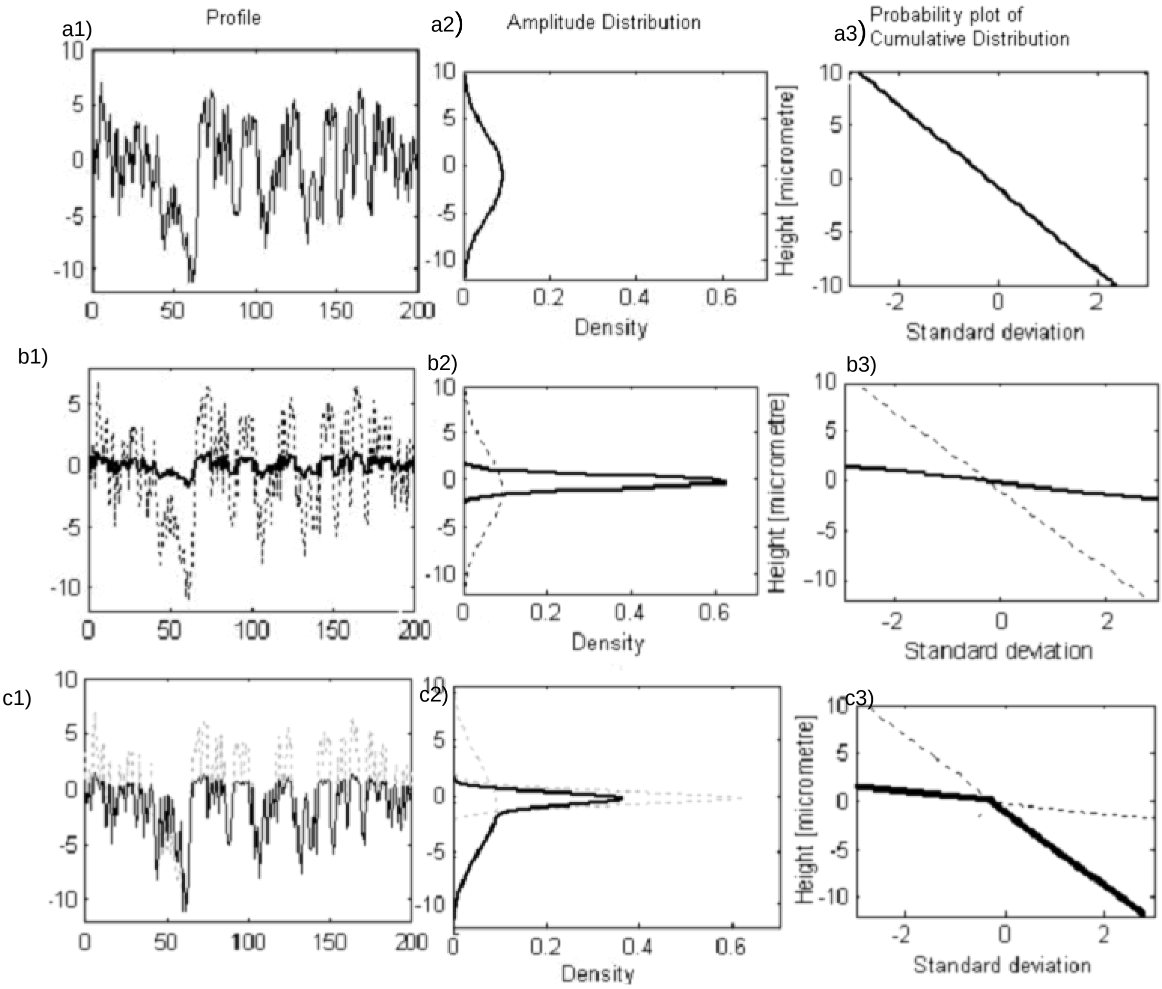

Figure 1. Graphical interpretation of parameters included in ISO 13565-3 standard

Model analysis

In simulation profile the abrupt transition between platau and valley takes place. Finding the transition point is possible by approximation the material probability curve by model 1 suggested by the authors of paper number 2.

$Y = a_o + a_1(x- x_0) + a_2(x - x_0)$ sign $(x - x_0)$ (1)

Where

sign - signum function

Y = sign(X), where each element of Y is:

1 if the corresponding element of X is greater than zero

0 if the corresponding element of X equals zero

-1 if the corresponding element of X is less than zero

The parameter (x_0 , a_o) determine the location of the join point, two straight lines are slopes $(a_1 – a_2)$ and $(a_1 + a_2)$ respectively [Watts, Bacon, 1971]. All parameters (a_o, a_1, a_2, x_0) which appear in this model can by evaluated on the base of date through they approximation by model 1.

Fig. 2 shows real profile roughness of 2-process surfaces and corresponds to graph of material probability curve. In this profile unstable area of transition (curve) between part of the top area plateau and the area of valley which is caused by mixture of two distribution (marked as 3) can be distinguished.

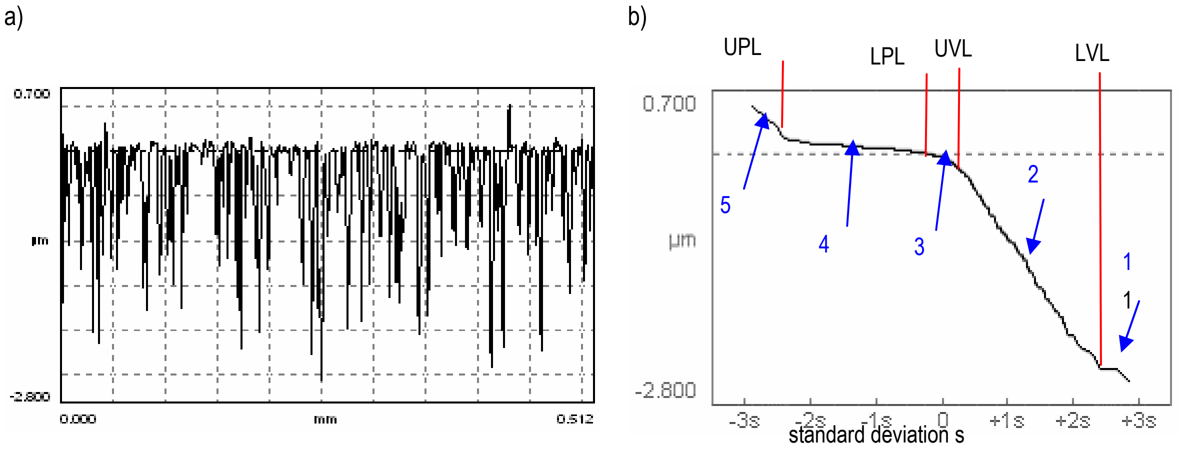

Figure 2. Example of roughness profile and corresponding graph of material probability curve

What is more, two linear areas (2 i 4) on the graph appear, which correspond to component profiles having a normal ordinate distribution. Moreover, this graph has two nonlinear areas, which come from:

- debris or outlying peaks in the data (profile) (labeled 5),

- deep scratches or outlaying valleys in the data (profile) (labeled 1) [ISO 13565-3].

The upper boundary of region (4) – "plateau" describes point Upper Plateau Limit (UPL), lower boundary of region – point Lower Plateau Limit (LPL), separating linear area (2) from nonlinear areas (5 and 3). The upper boundary of the region (2) – valley indicates point Upper Valley Limit (UVL), lower – point Lower Valley Limit (LVL), separates linear area (2) from nonlinear areas (3 and 1). To define value of parameter Rq from the region plateau and the region of valley properly, storage parts correspond to normal distribution should be separated.

Model (1) is only appropriate if it is known that an abrupt transition between plateau and valley takes place. In real profile the nature of the transition point from plateau to valley is not know a priori. Therefore was proposed more general model worked out by the authors paper number 2, which permits a smooth transition from plateau to valley by replacing the sign function sgn(x-x0) in 1 by transition function

trn $\{(x - x_0)/\gamma\}$

There are many transition functions which could be used but for this research used hyperbolic tangent function:

trn $\{(x - x_0)/\gamma\} = \tanh \{(x - x_0)/\gamma\}$

This function satisfy the conditions specified in [Watts, Bacon, 1971].

The genaral model (1) thus becomes

$$Y = a_o + a_1(x - x_0) + a_2(x - x_0) \tanh \{(x - x_0)/\gamma\} \qquad (2)$$

The parameters x_0 and γ determine the location of the join point and the radius of curvature of the model at the join point. In the limit, as γ approaches zero, model (2) devolves to two straight lines of slopes $(a_1 - a_2)$ and $(a_1 + a_2)$ respectively, intersecting at the coordinates (x_0, a_o). For nonzero γ model (2) is asymptotic to these two lines at values of x distant from the join point x_0 but at x = x_0 the curve passes through the join point (x_0, a_o). The radius of curvature R for the model (2) at the join point x_0 is:

$$R = \frac{\gamma}{2|a_2|}\left(1 + a_1^2\right)^{\frac{3}{2}}$$

Thus γ could be referred to as the radius of curvature parameter [Watts, Bacon, 1971].

The structure of program

To automatize the determination process of parameters Rq in plateau and valley area, computer program was created. This program was partly based on algorithm described in ISO 13565-3 standard. To find preliminary transition point from plateau to valley area, material probability curve graph was approximated (used nonlinear regression - algorithm Levenberg-Marquardt) by model 2. All parameters (a_o, a_1, a_2, x_0, γ) appear in this model can be estimated on the base on data by their approximated used model 2. Next graph point of value ordinate equal x_0 was used as preliminary transition point from valley to the plateau regions. According to methodology which is recommended in ISO 13565-3 standard, nonlinear material probability curve graph regions were eliminated (Fig. 2 – regions 1 and 5) and UPL and LVL points were assigned. Following step - material probability curve graph was normalized between points UPL and LVL towards y-axis coefficient:

$ks = (Y_{UPL} - Y_{LVL}) / (X_{UPL} - X_{LVL})$

and one more approximated in area between UPL and LVL using model (2).

In normalized graph lower boundary of the region plateau (UPL) and upper region valley (UVL) were determined by elimination *n* points which are situated partly right and partly left from point x_0. The number of eliminated points was determined from the value of radius of curvature *R.* In unnormalized graph linear regression lines between points UPL and LPL and between points UVL and LVL were determinated. Directional coefficients values of these lines were assigned as values Rpq and Rvq. Rmq parameter was assigned as value of abscissa in intersection of regressions lines assigned in plateau and valley region - Fig.3.

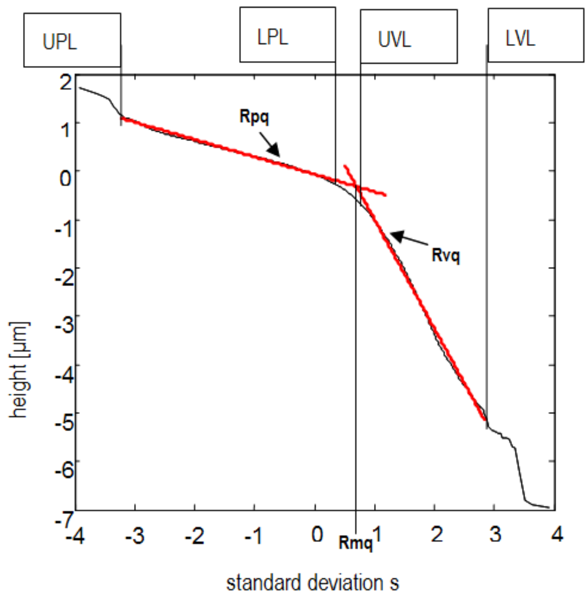

Figure 3. The graph of material probability curve and regression lines situated in plateau and valley regions.

Examples of results

In the aim of checking if prepared software assure proper value of roughness parameters, two-process profiles programmed Rpq, Rvq and Rmq parameters were modeled. The profiles after 2 processes were simulated using procedure presented in reference [Pawlus, 2008]. About quality of estimation these parameters one can find out on the bases of comparison parameters obtained after applying prepared software to programmed in model parameters (Table 1)

Table 1. Example values of parameters modeled profile of two-process surfaces (contains 8000 points) received with using suggested software.

Profile	Output parameters			Suggested software		
	Rmq [%]	Rpq [µm]	Rvq [µm]	Rmq [%]	Rpq [µm]	Rvq [µm]
T1	84.1	0.1	4	88.78	0.15	3.843
T2	15.9	0.1	4	11.81	0.17	4.25
T3	80.1	0.3	2.47	82.70	0.336	2.74
T4	50	0.6	5	53.87	0.56	4.89
T5	97.7	0.1	6	94.85	0.18	5.12
T6	78.5	0.36	2.25	75.33	0.312	1.92
T7	78.8	0.36	4.54	81.98	0.345	4.12
T8	84.1	0.3	4	89.15	0.41	3.703

In case of analizing modeled profiles, it was found that the most proper results one received when values of parameter Rmq were in range from 17% to 82%. In other cases obtained results differed from values come from the given model. Figures 4 shows the examples of the parameters calculation results for sample T4.

a) b)

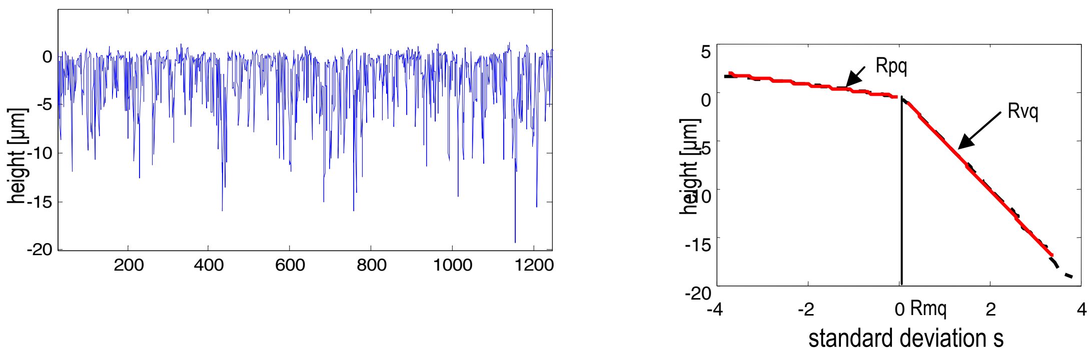

Figure 4. Modelled two-process profile (a) (sample T4), probability plot of height distribution (b) Ppq = 0.56 μm, Pvq = 4.89 μm, Pmq = 53.89%

Real profiles were also tested. While analysing measured profiles one can define accuracy of determinated parameters on the base of approximated graph material probability curve. It was found that the errors of parameters are bigger when the ratio of Pvq to Ppq were very small.

Conclusion

In the aim of better understanding the properties of surfaces having stratified functional properties and their connection with using properties, precise description should be applied. Accurate description of these surfaces using only one parameter is very difficult, because independent components appear which should be characterized very precisely and rather separately.

Independent description of particular components of those profiles enables their better understanding. It can make a contribution for better progress in designing these types of surface structure. Automatic determination of surfaces parameters having stratified functional properties improves their process of control. Proposed software reach out this mentioned expectation.

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