THE AUTOMATION OF PARAMETER PPQ IDENTIFICATION PROCESS FOR PROFILES WITH FUNCTIONAL PROPERTIES

Wiesław Graboń

Abstract: *Methods and standards to determine Ppq parameter for profiles with periodical-random character, which are of functional importance, have not been developed yet. This article proposes a method to solve this problem. Furthermore, an equation describing this kind of profiles, and method of constructing software which uses this equation for calculating roughness parameter were described.*

Keywords: *algorithms, multi-process surfaces, roughness parameters.*

ACM Classification Keywords: *Algorithms, Measurement.*

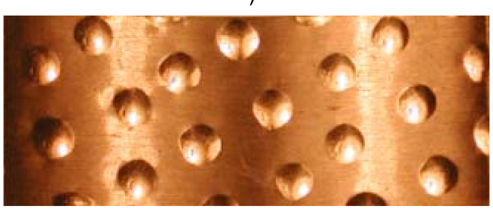
Introduction

In modern manufacturing techniques the basic goal is to obtain good quality connected with specific quality of surface layer processing machining articles. Strong connections exist between the state of surface layer and the ability of this surface layer to perform different performance requirements by machine parts.

The external surface is an integral part of surface layer. The geometrical structure of the surface has fundamental influence on operating properties such as: tribology wear resistance, stiffness of butt join, fatigue strength, thermal conductivity, flow resistance, coating density and others.

The importance of multi-process surfaces has recently increased, because every "element" of these surfaces influences particular functional and working properties of machine parts. Multi process surface textures are considered surfaces having stratified functional properties. Among these surfaces, surfaces which have periodical-random and random-periodical structures are vital. Bottom layers of these surfaces include oil pockets created in different ways for example: electrochemical etching, laser method or burnishing (fig. 1). Usually these oil pockets have periodical character.

a)



b)

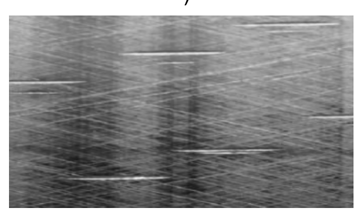


Figure 1. Examples of: a) surface bearing liner which includes oil pockets,
b) cylinder liner surface with burnished oil pockets.

For better density of date accumulation on magnetic discs, the slider should move nearby rotating disc in gaseous lubricants condition. In order to reduce the static friction and increase the life of the disc, valleys on the surface of the disc are created near fare internal edge of the disc [Talke, 1995]. Theoretical research in this area was conducted by the authors of publication [Tagawa, Hayashi, Mori, 2001]. The analysed surfaces were covered with rectangular prisms, the distance between which was 60 μm in circumferential and 40 μm in axial direction. Horizontal dimension of rectangular prisms, and the distance between them have influence on the position of the slider during its movement in relation to the disc which rotates around its axis (it should be the lowest possible position). It was found that structure showed in fig. 2. in B configuration is optimal.

Usually laser technique is used to create valley texture on the surfaces of discs. Valleys created by means of this technique have toroidal or sombrero shape. They usually have inside diameter of 10 - 15 μm and height of 15 - 25 nm. The authors of research [Cha, Lee, Han, Lee, 1999] found that creating valley on a hard disc surface cause smaller static friction force in comparison with a disc without valleys which had undergone mechanical working in start and stop zone. Another possibility is to create valleys on the surface of a slider which interacts with a smooth disc. The author of paper [Suh, Lee, Polycarpou, 2004] stated that this solution reduced the inclination to adhesion, and friction force compared with smooth surfaces.

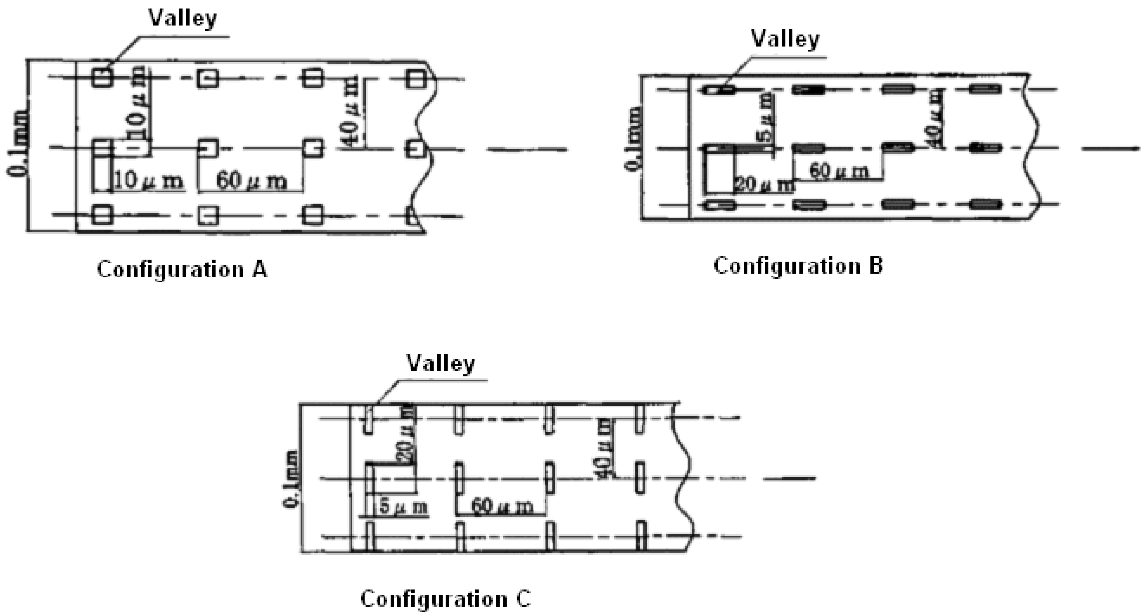
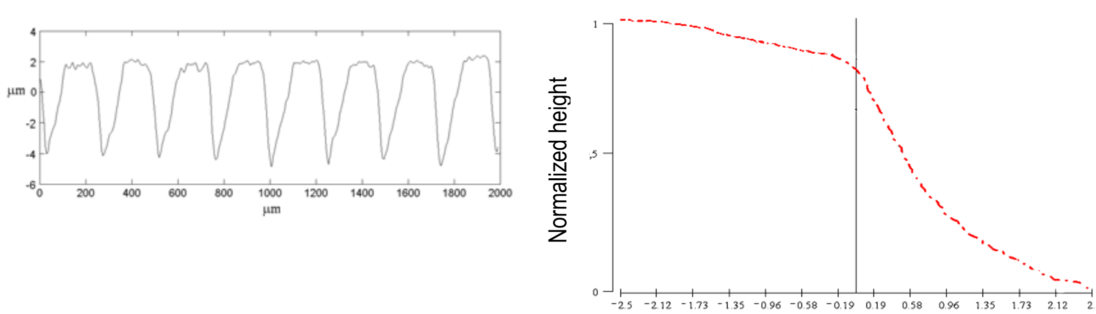


Figure 2. Configurations of surfaces analyzed in the article [Tagawa, Hayashi, Mori, 2001]

This kind of surfaces topography is usually described by giving depth, width and length of valleys, and degree of coverage with valleys. Values of parameters Ra and Rq are also given for better description of these surfaces.

Other examples of surfaces which have periodical-random character are surfaces of piston skirt before exploitation. Top part of this surface has random character while valleys have periodical character after being turned (fig. 3). Surfaces topography of piston skirt during zero wear can be described with parameters: Sq, SΔq and Sp/St. Additionally, Str, Std, Sds (or SΔq/Sq) and St are proposed. The description of axial profiles of piston skirt before working includes the following parameters: Pq, Psk (Pp/Pt), Pku i PΔq [Krzyżak, 2005]. Methods and standards to determine Ppq i Pmq parameters profiles with periodical-random character which are functionally vital haven't been developed yet. This article proposed a method to solve this problem.



a) b)

Figure 3. Axial piston skirt profile with abrasive wear of little degree, and with original shape of triangular (a), and its probability plot of cumulative distribution with normalized height (b) [Krzyżak, 2005].

Model analysis

The process of formation of periodical-random profile (for example during wear) is shown in fig. 4. Amplitude distribution of roughness profiles of surfaces which have stratified functional properties and include traces of two processes, does not have normal distribution. Nevertheless, we can make an assumption that in this case, for this type of surfaces, the surface with normal distribution and surface with rectangular distribution overlap. Therefore, the first step to describe independently these two overlapping surfaces is modeling every component as a different distribution.

The profile presented in fig. 4 a1, shows the geometrical structure of a surface before initial machining process. The probability plot of cumulative distribution of this profile is shown in a3, and fig. a2 shows the amplitude distribution for this profile. Profiles which are illustrated in fig. 4b1 and c1 present the model of periodical surface after different periods of being used. Figs b3 and c3 show probability plot of cumulative distribution of these profiles and fig b2 and c2 show amplitude distribution for these profiles.

In laboratory conditions only the final profile is measured (profiles on fig. 4 b1 and c1). On this profile there are only the deepest valleys of the initial rough surface (triangular profile) which are represented by red line in the bottom part of the chart with amplitude distribution (fig. b2 and c2) – it results from ordinate distribution of triangular profile.

The upper part of the initial roughness profile is deleted and replaced with a less rough structure of the surface (so called plateau) with random character of density distribution axis. It is illustrated in the blue part of the amplitude distribution chart (fig. 4. b2 and c2).

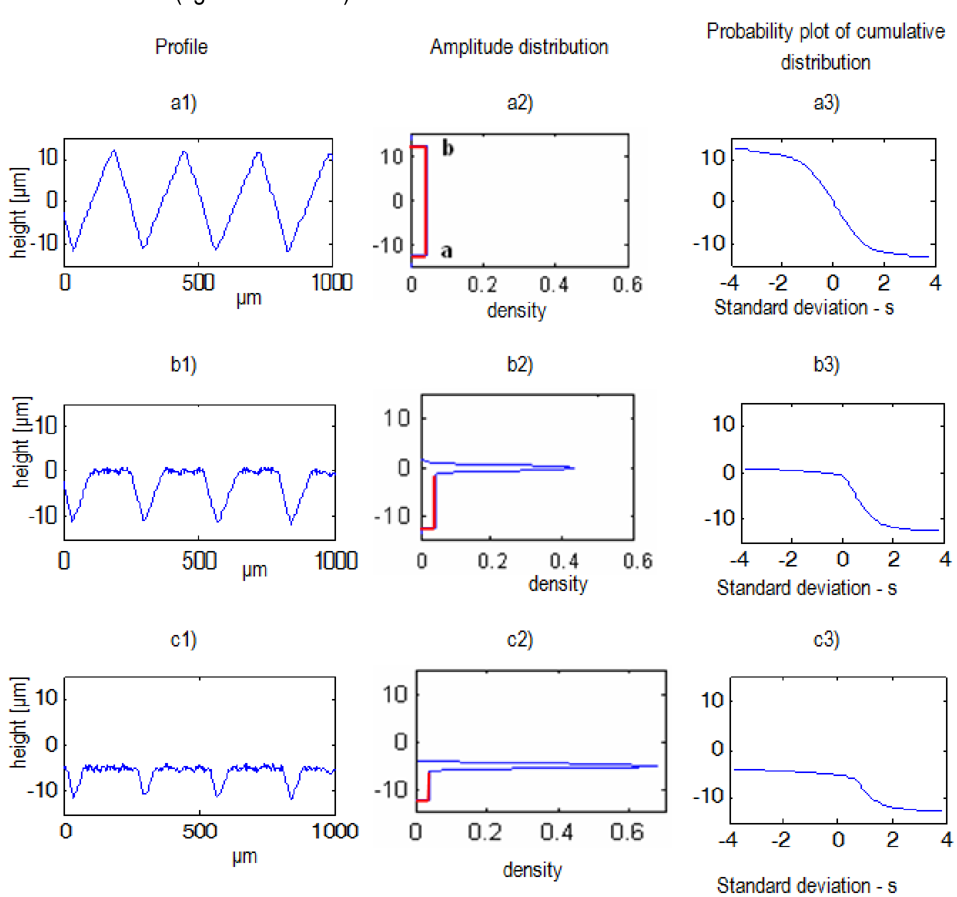


Figure 4 Profile which has a periodical character (a1), its amplitude distribution (a2) (in portions between a and b), probability plot of cumulative distribution (a3), profiles with periodical-random character (b1, c1), and their amplitude distribution (b2, c2) and probability plots of cumulative distribution (b3, c3).

Based on the research the authors of publication [Oczoś, Liubimov, 2003], who assumed rectangular distribution of axes for triangular profile (which can be concluded from amplitude distribution shown in fig. 4 a2), the methodology of assigning parameter Ppq based on amplitude distribution may be proposed. In this methodology amplitude density distribution of periodical-random profile should be approximated by the following function:

$$f(z) = f_1(z)\cdot\left(1-\int_{-\infty}^{z} f_2(\xi)d\xi\right) + f_2(z)\cdot\left(1-\int_{-\infty}^{z} f_1(\xi)d\xi\right)$$

$$f_1(z) = \begin{cases} \dfrac{1}{b-a} & \text{when} \quad a < z < b \\ 0 & \text{when} \quad z \le a \ \text{or} \ z \ge b \end{cases} \qquad f_2(z) = \frac{1}{\sigma\sqrt{2\pi}} e^{-0.5\left(\frac{z-\mu}{\sigma}\right)^2} \quad \text{when} \ z \in (-\infty, \infty) \tag{1}$$

where:

z- height of roughness profile,

μ and σ – mean height and standard deviation of axis secondary profile with random character,

a, b – rectangular distribution beginning and end.

Calculated value of standard deviation (σ) constitutes value Ppq parameter.

Implementation

To automate the determination process of parameter Ppq in plateau area, a computer program was created. In this program preliminary estimation of density distribution axis of profile was done with the use of Parzen window method. In the next step density distribution obtained as a consequence of using Parzen window method was approximated with the use of function (1) in the nonlinear regression method.

The value of standard deviation, mean of normal distribution, and rectangular distribution beginning and end were obtained. According to the principles of the model, the value of standard deviation becomes the value of Ppq parameter. Figure 5 shows examples of the results of calculating the parameters.

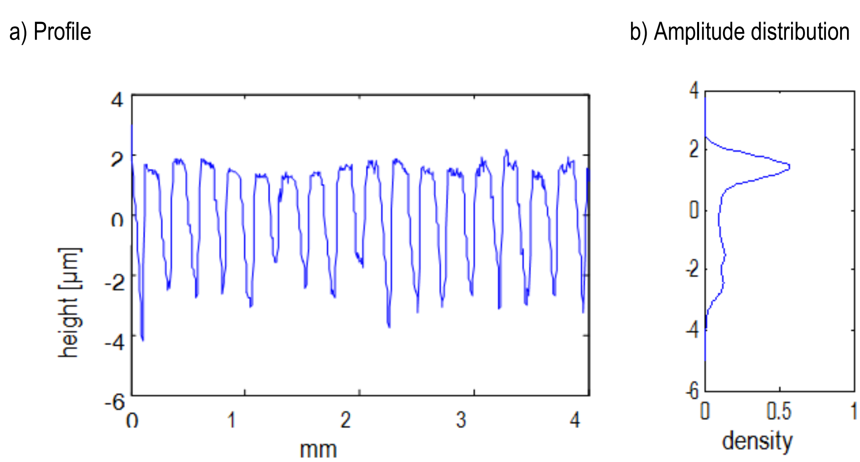


Figure 5. Profile of piston skirt surface before wearing (a), and amplitude distribution received after working program (b) for which value of parameter Ppq equals 0.35 µm.

Conclusion

During friction in the presence of lubrication, excessively smooth surfaces badly hold lubricant (which can cause seizing up interacting parts of a machine). On the other hand, too rough surfaces wear too quickly. One way of improving tribological properties of machine parts is creating oil pockets on interacting surfaces.

Oil pockets may increase aerodynamic lift with the use of cavitation mechanism or they can create tanks with leaking oil, which can decrease the contact of interacting surfaces (lower speed) [Nilsson, Rosen, Thomas, Wiklund, Xiao, 2004]. In both of these cases friction force is minimized. Oil pockets may also serve as traps for abrasive solids. One example of this kind of surfaces are periodical-random surfaces.

For better understanding of functional properties for this kind of surfaces, and for connecting these properties with functional quality, a precise description should be realized. Such description with the use of only one parameter is very difficult, because this kind of surfaces have independent components of their structure which should be characterized separately and very precisely. Independent description of particular components of these surface profiles enables us to better understand their working, but methods and standards to describe the plateau part of these profiles characterized by Ppq parameter have not been developed yet. Therefore, methodology for calculating Ppq parameter for this kind of profiles was proposed. Automatic determination of this parameter improves the process of controlling this sort of surfaces. The proposed software meets the above mentioned expectations.

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Authors' Information

Wiesław Graboń *– Department of Computer Science, Rzeszow University of Technology; W. Pola 2, 35-959 Rzeszów, Poland ; e-mail: wgrabon@prz.edu.pl*

Major Fields of Scientific Research: Software engineering information systems, Modeling of manufacturing processes.