3D-numerical Model of Surface after Laser Machining

[1]J. Jablonski, [2]S. Pawlowski, [3]V. Liubimov

[1]Department of Technics, University of Rzeszow, ul. Rejtana 16 a
[2]Department of Electric, Rzeszow University of Technology, ul Pola 2
[3]Department of Technology, Rzeszow University of Technology, ul Pola 2
Email: jjablons@univ.rzeszow.pl,

Abstract. *The paper presents digitally created 3D model of metal surface. This surface has stationary and ergodic character. Its model represents surface after laser treatment. Cross-sections 2D are quasi-periodic. Fractal structure was imposed on the surface. Abbot-Firestone Pmr(c) and height distribution curves z(x) in 2D and 3D systems (according to ISO 4287-2000) were analysed.*

Keywords: simulation of topography, laser processing, fractals

1. Introduction

Computer simulation is a useful tool particularly in the field of manufacturing process. It allows us to shorten time of investigations and to reduce costs of changing or modification of existing technologies. The analysis of surface topographies after finishing processes is one of these methods. Computer generation of these structures makes forming of real surface easier. The aims of these investigations could be for example anticipation of surface functional properties. Parameters derived from material ratio curve Pmr(c) can be representative distinguishing values of these textures. It is believed that they are strongly correlated with surface functional properties, for example frictional wear resistance.
Fractals are mathematical (strictly geometrical) creatures. They can have non-integer dimensions, it is the main difference between them and classic geometrical objects. They usually posses self-similar structure: the same or similar outline with various magnifications. For classical self-similar curves the reduction coefficient can be facultative, for example 0.13, 1/27. However these coefficients are strictly determined for fractals; they depend on concrete shape. Dependence between reduction coefficient (so-called scale coefficient) and the number of reduced fragments "a' is the common feature of self-similar objects [1]

$$A = \frac{1}{S^d}\,; \qquad d = \frac{\log "a"}{\log 1/S} \quad \ldots \tag{1}$$

where d – self-similarity dimension. It is one of the forms of fractal dimensions. Of course there are other forms, for example compass or box dimensions [1].
Box dimension is the best for topography of engineering surfaces after manufacturing processes modelling (these surfaces have both self-similar and non self-similar structures).
For example box dimension was used for estimation of fractal dimension of anisotropic surfaces [2].
Hausdorff dimension is a classical example of fractal dimension [1].

2. The idea of fractal iterations

In the majority of research works in these field fractal iterations are done till fractal dimension is determined. In model proposed here it can be possible but it is not necessary. It is a result of the choice of similarity criterion between the model and real surfaces. On can say that some kind of fractal interpolation is used here. The sections (at various angular positions) were analysed using bearing length and area ratio curves. The analysis of computer generated surfaces allows us to avoid ambiguity during interpretation of results of roughness measurement. This ambiguity is the result of variety of profilometer used in industry (various productions date, various companies, not well known numerical procedures, different verification criteria [3]).

Model presented here was developed by simultaneous execution of fractal sequences along x and y axes (see Fig. 1). It assured stationarity of surfaces (stationarity of random area according to nomenclature of random signals [4]).

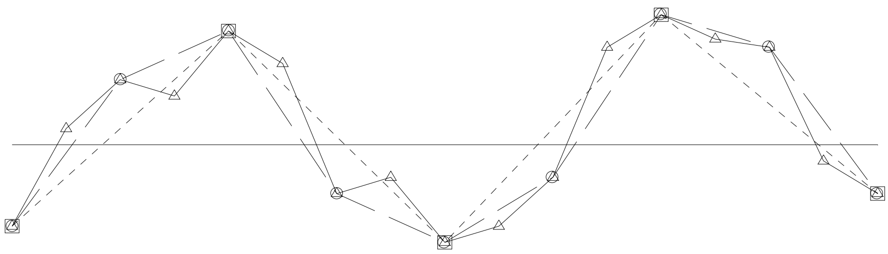

Fig.1. Example of generated surface - intersection 2D (fragment).

Gaussian distribution was the base of random numbers generator. It assured ergodicity of surface. Fractal sequence determines the horizontal (frequency) features. Ordinates generated according to Gaussian distribution represent amplitude characteristic of surface.

Essence of 3D-fractal topographical structure formation depends on joint usage of ordinates of Gaussian distribution sampling and fractal iteration. In first stage selection of the mean height value and selection of scatter of heights R from average value take place. In HF programme (own generating software) R= 6σ, where σ - standard deviation. In this manner surface smoothness was determined. Then selection of random numbers in the range $\pm 3\sigma$ takes place (Gaussian generator). These numbers are distributed in distances equal to sampling intervals. Then described procedure (iteration) is repeated. However coefficient I (0<i<1) could be introduced in first iteration. It depends on kind of surface treatment (and also of modelled surface). This coefficient also symbolises, say confidence to hypothesis assumed and also degree of impatience of researcher (who uses HP software). Intuitively, it is believed that the number of fractal iterations can simulate interaction between cutting edge geometry and tool kinematics.

3. Digital surface model

The real surface after laser treatment was input object of investigation (see Fig. 2). Characteristic features and roughness parameters 3D of this surface were measured using Talymap 3D – Talyscan 150 profilometer. The following measuring conditions were used: measuring stylus speed 2000 μm/s, form removed: Polynomial of order 3.

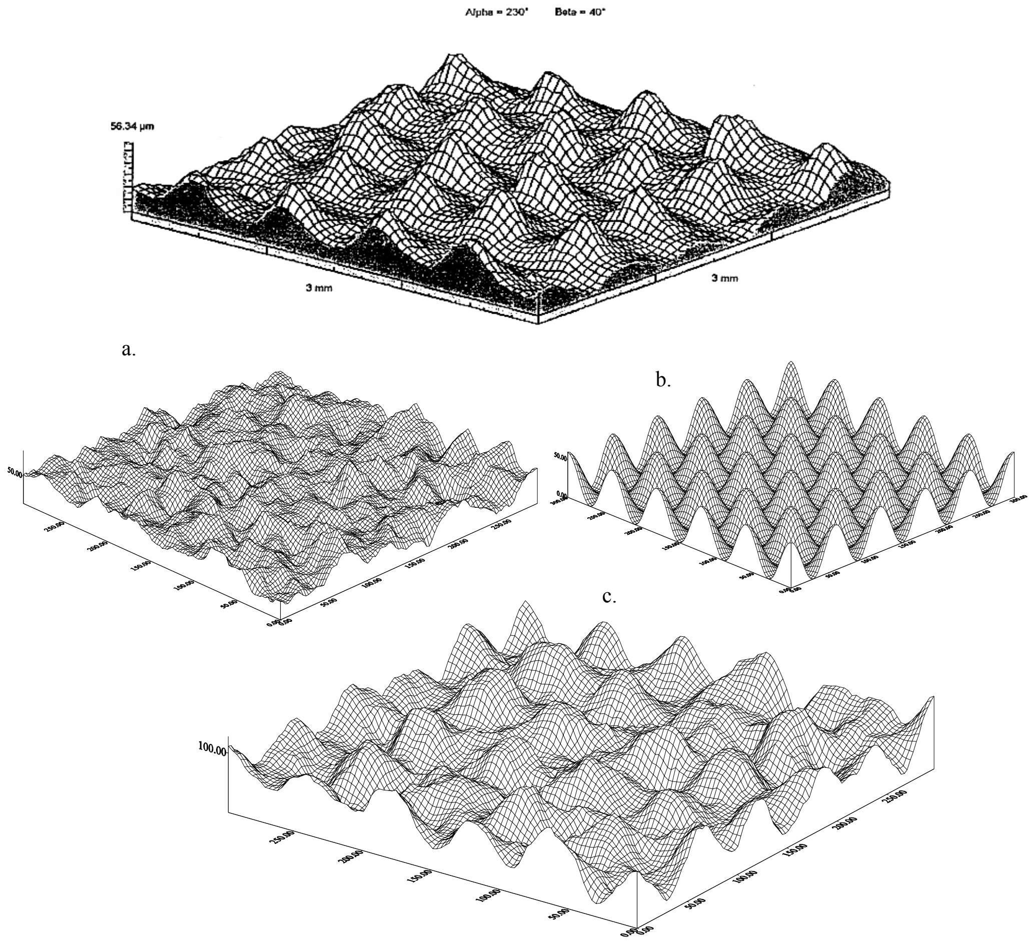

Fig. 2. At the top - topography of real surface – printout for Talyscan 150 profilometer, a) fractal surface, b) base surface, c) superposition of base surface and fractal structure being a digital model of laser treatment.

Whole surface topography was analysed here (without division into waviness and roughness), because during tribological wear it is not important whether surface has or not long waves. In most cases the functional behaviour is influenced by the totality of the microgeometrical deviations so there is not reason for separating roughness and waviness.

Material ratio curves of profile irregularity and surface topography were recognised as cumulative ordinate distribution functions. Kolmogorov test was used to verify compatibility of empirical and theoretical distributions based on the mentioned curves and histograms, assuming the substantiality level.

Construction of digital virtual form of real surface consists from the following stages:

1. Creation of base (main) topography form. This form represents specification of laser treatment
2. Imposition (superposition) fractal stricture on base form (according to procedure described in p 2)
3. Selection of similarity criteria between real surface ant its digital model
4. Checking if this model is adequate

Figure 2 illustrate stages 1 and 2. Material probability curve and ordinate distribution histogram 3D were selected as similarity criteria between real surface and its digital model. Special own software HF enables change of surface topography in digital virtual space.

The change of average void volume along height was given as the example.
Both this changes as well as different transformations of virtual surface form take place in constant height range (Zmax-Zmin) according to laser treatment specification (periodicity and isotropy of surface).
Average void volume could be one of the criteria of modification of input form of surface topography. The change of void diagram was implemented by change of harmonic (sinusoidal) component frequency of base form.
This idea originates form digital signal processing theory. That is: " if input signal is the sum of sinusoidal components then output signal will have components of the same frequencies, but different amplitudes and phases". It comes from Fourier analysis.

4. Conclusions

1. Accepted similarity criteria between virtual model and real surface have statistical character. They concern height characteristic of surface topography and could be quantitatively expressed, in form of, for example gradient in specific curve points of material probability curve or values of histogram parameters.
2. In spite of limitation described in point 1 the virtual model can be used for surface topography forming according to functional criteria, for example Vko – see Fig. 3. It is illustration of one of software HF possibilities.

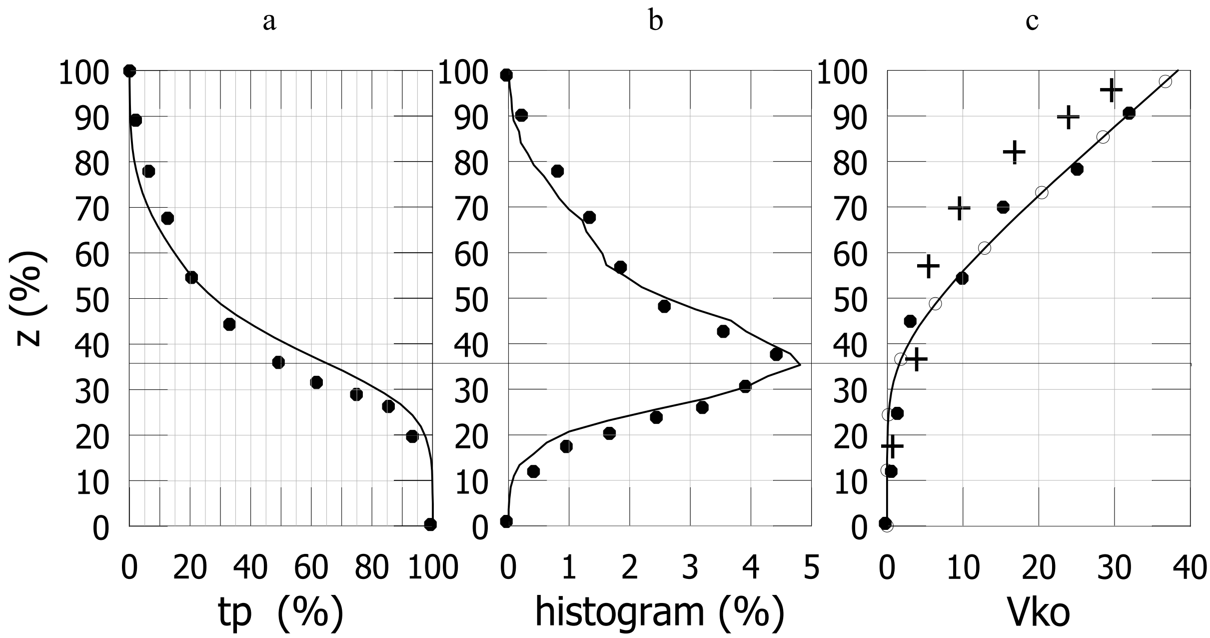

Fig. 3. a - material probability curve, b – histogram, c - course of average void volume;
——— - for real surface, ● - for digital model, + - after digital modification of virtual model.

References

[1] Peitgen H. O., Iurgens H, D. Saupe A.: Fractals for the Classroom. New York, 1992.
[2] Blackmore D., Zhou G.: A new fractal model for anisotropic surfaces, 7th Int. Conf. on Metrology and Properties of Engineering Surfaces, Gothenburg 1997, pp. 147-153.
[3] Jablonski J.: Problems of the measurement of standard of surface roughness parameters, 4th Conf.of the Egyptian Society of Tribology, Cairo, 1995,pp. 271-279.
[4] Bendat J. S., Piersol A. G.: Random Data : Analysis and Measurement Procedures. New York, London, Wiley, 1971.