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INVESTIGATION INTO THE ACCURACY OF 3D SURFACE ROUGHNESS CHARACTERISTICS

M. Kumermanis, J. Rudzitis, N. Mozga, A. Ancans, A. Grislis

Riga Technical University,
Institute of Mechanical Engineering,
6 Ezermalas Str., Riga, LATVIA
e-mail: arai@latnet.lv

The existing standards for surface roughness cover only two dimensions, while in reality this is three-dimensional (3D). In particular, the 3D surface roughness parameters are important for solving the contact surface mechanics problems as related to the accuracy of 3D surface roughness characteristics. One of the most important factors for determination of 3D characteristics is the number of data points (NDP) on the *x*- and *y*-axes (i.e. in cut-off length). The NDP has a profound effect on the accuracy of measurement results, measuring time and volume of the output data (especially along the y-axis, where the NDP is identical to the number of parallel profiles). At a too small NDP the results will be incorrect and with too broad scatter, while a too large NDP – though not enlarging the range of basic information – considerably increases the measuring time. Therefore, the aim of the work was to find the optimal NDP for such surface processing methods as grinding, spark erosion and shot methods of surface treatment.

Keywords: Surface roughness, number of data points, graphical approximation.

1. INTRODUCTION

In measuring the 3D surface roughness it is necessary to collect a definite number of points (in our case profiles or lines parallel to the main axis of the sample). The surface displacement occurs in two orthogonal directions: *x* and *y* (Fig. 1). In the *x*-direction the data are collected with *Nx* being the number of data points, whereas in the *y*-direction there are *Ny* lines (profiles) [1].

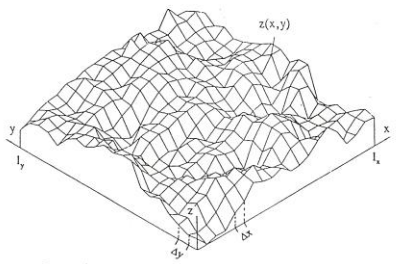

Fig. 1. 3D measurement scheme of surface displacement.

To determine the optimal number of data points (NDP) three specific experiments have been conducted. Under investigation are the benchmarks for (flat) grinding, spark erosion and shot methods of surface treatment.

2. NDP DETERMINATION BY CORRELATION FUNCTIONS

To determine the optimal NDP three experiments have been conducted using a Taylor Hobson Intra 50 measuring device and the Talymap Expert software.

The aim of the experiments was to determine the minimum of uncorrelated NDP on the average spacing of the roughness profile. The surface roughness of irregular surfaces (ground, polished, machined with spark erosion, coated, etc.) can be described by a normal random process [2]. One of the basic characteristics of such a process is the correlation function which describes the coherence between profile points. For determination of this function, so-called special points of surface splits are used: the profile intersections with the mean line, the local maxima, and the bending points. These special points are shown in Fig. 2, where *l* is the cut-off length.

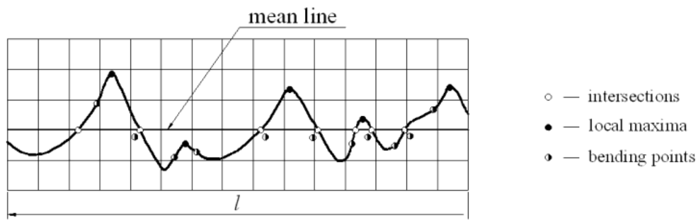

Fig. 2. Special points of the roughness profile.

To determine the output data, five profile charts were taken for each surface according to the profile measurement methods [2]. The mean profile deviation and the profile special points were read from the profile charts in one sampling length (0.8 mm); for further calculations the averaged values were used. Calculation procedure for the surface grinding process is exemplified as follows.

1. To obtain the output data. After processing a profile chart these are:

   Ra = 1.57 μm – the mean profile deviation;
   $n(0)$ = 25 – the number of intersections with the profile mean;
   m = 37 – the number of local maxima;
   s = 47 – the number of bending points.

2. To define the dimensionless parameters of the correlation function that are needed for determination of its type [2]:

$$\lambda \approx \frac{n(0)}{m} \approx \frac{25}{37} \approx 0.68 \; \lambda_S \approx \frac{n(0)}{s} \approx \frac{25}{47} \approx 0.53 .$$

These values of dimensionless parameters correspond to the first type correlation function K_τ [2].

3. To determine the first type correlation function K_τ and its parameters:

$$K_\tau = \left(1+\alpha\tau^2\right)^{-1}; \; \alpha_H = 0.5 \; ; \quad 0 \le \lambda \le 2 \; ; \tau_{KH} = 0.71\,\text{mm} ,$$

where α is the non-dimensional coefficient;

τ is the distance between points;

α_H is the normalized α value;

τ_{KH} is the rationed correlation function interval.

4. To calculate the correlation interval τ_K :

$$\tau_K = \frac{\tau_{KH}}{n(0)} = \frac{0.71}{25} = 0.028\, mm .$$

5. To calculate the mean spacing *RSm* of the profile on the sampling length (0.8 mm):

$$RSm = \frac{2}{n(0)} = \frac{2}{25} = 0.08\, mm .$$

6. To determine the NDP along the sampling length:

$$k = \frac{l}{\tau_k} = \frac{0.8}{0.028} = 29 .$$

7. To determine the number of spacings on the sampling length:

$$z = \frac{l}{Sm} = \frac{0.8}{0.08} = 10 .$$

8. To determine the number of uncorrelated data points in one spacing:

$$Ps = \frac{k}{z} = \frac{29}{10} = 2.7 \Rightarrow 3 .$$

In a similar way it is possible to find the NDP for any surface.

3. NDP DETERMINATION BY GRAPHICAL APPROXIMATION

Another method for the NDP determination is to describe the roughness using a graphical approximation (Fig. 3). In this case, from one surface roughness profile chart one asperity in the x-axis direction is taken (Fig. 3*a*).

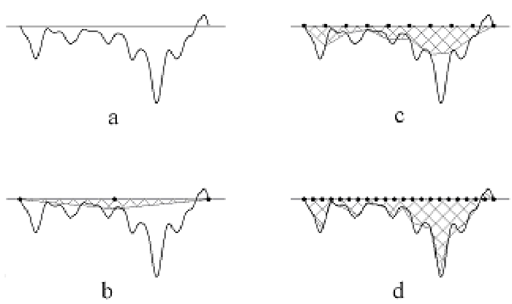

Fig. 3. Roughness approximation at different NDP values:
a) the real roughness of a ground surface;
b, c, d) the roughness described by 3, 10 and 22 points, respectively.

Here the number of data points is sought-for at which the approximated parameter – in our case the total deviation of the roughness height from the real total height *Rt* – is < 5%.

4. STABILIZATION OF ROUGHNESS PARAMETERS: DETERMINATION OF RELEVANT NDP

In this case, we determine the number of data points at which the permissible deviation of stabilized parameter (e.g. *Ra*) is ≤ 5% (see Table 1). For the determination, the surface roughness profile charts are taken in the *x*-axis direction, repeatedly in the same place at a different NDP and the same cut-off length. The measurement results are shown in Fig. 4. The measurement error is here 2% ±6 nm (defined by the manufacturer of the measuring device). As seen from this figure, in the case of surface grinding the values of parameter *Ra* begin to stabilize at NDP = 30.

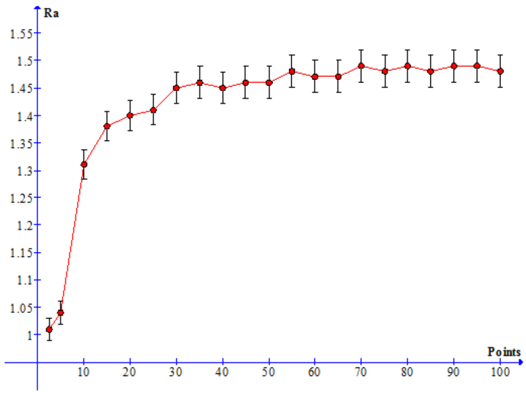

Fig. 4. Coherence of mean profile deviation *Ra* and the number of data points.

Table 1

Number of data points

<table>
<tr><th rowspan="3">Surface processing method</th><th colspan="6">Method</th></tr>
<tr><th colspan="2">Random function theory</th><th colspan="2">Graphical approximation</th><th colspan="2">Parameter stabilization</th></tr>
<tr><th>points</th><th>inaccuracy</th><th>points</th><th>inaccuracy</th><th>points</th><th>inaccuracy</th></tr>
<tr><td>Flat grinding</td><td>3</td><td>88%</td><td>22</td><td rowspan="3">5%</td><td>30</td><td rowspan="3">2%</td></tr>
<tr><td>Spark erosion</td><td>5</td><td>23%</td><td>14</td><td>20</td></tr>
<tr><td>Shot</td><td>5</td><td>8.4%</td><td>14</td><td>20</td></tr>
</table>

5. CONCLUSIONS

Analysis of the NDP determination procedures has shown that it is possible to do this for the random surface processing using the roughness structure.

The NDP determination by correlation functions does not give acceptable results, which is explained by significant deviations of the actual surface roughness from the theoretical model. The method of graphical approximation and the number of data points at which the roughness parameters stabilize give a sufficiently good match. Consequently, the NDP can be determined as the averaged value from the two methods.

Taking into account the tabulated results of the last two methods, for irregular 3D surface roughness measurements the value NDP=22 in roughness mean spacing (inaccuracy 2-5%) should be recommended. This number of data points can also be used for coated surfaces, since the character of their roughness in general is irregular.

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3D VIRSMAS RAUPJUMA RAKSTUROJUMU PRECIZITĀTES PĒTĪJUMI

M. Kumermanis, J. Rudzītis, N. Mozga, A. Ancāns, A. Grīslis

K o p s a v i l k u m s

Eksistējošie virsmas raupjuma standarti apskata virsmas raupjumu tikai divās dimensijās. Tomēr reālais virsmas raupjums pēc savas dabas ir trīsdimensiju (3D) objekts. Līdz ar to virsmas raupjums ir jāraksturo ar 3D parametriem. Un no šo parametru noteikšanas precizitātes ir atkarīgi tālākie virsmas aprēķini, piemēram, virsmu kontaktēšanās process.

Viens no svarīgākajiem faktoriem, raksturojot virsmas raupjumu 3D, pielietojot kontakta tipa mēriekārtas, ir datu punktu skaits pa abām mērīšanas asīm x un y. Ar datu punktu skaitu mēs saprotam to skaitu mērīšanas bāzes garumā. Datu punktu skaits būtiski ietekmē sagaidāmo mērījumu rezultātu precizitāti, mērīšanai nepieciešamo laiku un izejas datu faila izmērus (sevišķi y-ass virzienā, kur katrs datu punkts ir paralēls profils). Datu punktu skaitam ir jābūt optimālam. Pārāk mazs punktu skaits noved pie neprecīziem rezultātiem un lielas to izkliedes, savukārt pārāk liels punktu skaits nedod būtisku informācijas pieaugumu, bet palielina mērījumam nepieciešamo laiku. Līdz ar to, mums ir jāatrod optimālākais datu punktu skaits katrai virsmas apstrādes metodei vai to grupai.

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