The Effect of Surface Roughness on Components Size Measurement Errors

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Abstract

When measuring the size of machine parts using the universal measurement means, it is also necessary to consider surface roughness of the measurable machine parts. Large roughness is causing additional measurement errors. It is important for thin polythene with nanostructure coating surfaces.

The theoretical calculations of the above mentioned error are covered in this paper. It is based on surface roughness model in random field form by using its normal distribution of regularities. This work will address the errors from a theoretical perspective. The surface roughness profile satisfies the normal proability distribution law for surfaces nano-coating or machining operations such as grinding, homing, polishing, etc [2].

In this case it may be verified, that for normal random field form described surface it is necessary to know only one parameter of roughness height and two different spacing parameters.

Based on classical elasticity theory there are developed coherences which are linking measurement force with deformation of machine parts surface, what is reason of measurement error.

1 Surface roughness and measurement process

Considering the surface roughness as the normal homogeneous random field, it is possible to take a relatively simple output data (Ra and spacing in two perpendicular directions), through which is determined all interested micro-topography parameters. This allows escaping of an experimental all the micro-topographic characteristics determination, it is necessary determine only the output data. The measuring process of details linear dimensions are characterized

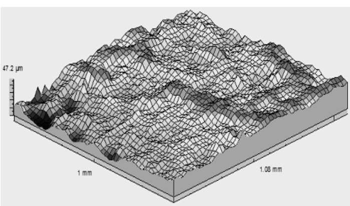

Figure 1. Measured surface 3D

by low load and small contact area, as only elastic deformation is permissible. As a result, the expected deformations will be low. Measurement of high precision parts, where the manufacturing tolerances are few micrometers, the measurement error is comparable to the deformation of roughness peaks. It is 20 – 35% of manufacturing tolerance. It is required to consider with deviation as result of the roughness deformation in such cases.

2 Contact of two surfaces

To determine the elastic deformation of the details surface roughness, admit that the contact occurs between the rough surface (measured detail) and the perfectly smooth surface (measuring equipment). However, perfectly smooth surface does not exist in real life. Therefore, it is possible to calculate the contact of two rough surfaces with different roughness parameters using the following scheme. Movement of ideal plane is not perfectly parallel to rough surface, but these deviations are insignificant, so in the theoretical calculations they are not taken into account. Consider the following ideal plane and rough surface contact scheme: in affect of the added force P the ideal plane moves from the position $I – I$ to position $II – II$ where the balance between external forces and micro-roughness deformation resistance is provided. In this position, the distance between the ideal plane and the average plane of roughness is equal to u (fig. 2).

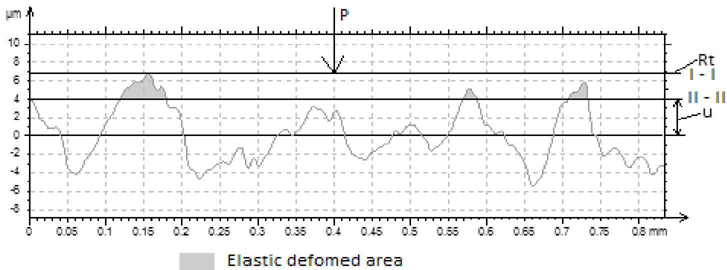

Figure 2. Measured surface profile

As mentioned above, in measuring only elastic deformation is allowed, therefore it is important to clarify the deformation of the roughness peaks. Such deformation calculation equation depends on form of the single roughness peak. Analytical researches show that the shape of peak is close to an elliptic parabola. After the elastic deformation of such peaks is provided, the contact area form becomes elliptical. Then the contact area can be calculated as following:

$$A_{\mathrm{el}.i} = \pi a_i b_i \,, \tag{1}$$

where a_i, b_i - small and large semiaxis of the contact area.

Based on the classical theory of elasticity it is possible to get the value of a_i, b_i and deformation of single roughness peak α using the following equation:

$$b_i = \left[\frac{3E(e)\Theta P_i}{2\left(1-e^2\right)H}\right]^{1/3} \quad ; \quad a_i = b_i\left(1-e^2\right)^{1/2} ; \qquad \alpha = \frac{3}{2}K(e)\frac{\Theta P_i}{b_i} \,, \tag{2}$$

where $K(e)$, $E(e)$- first and second order elliptic integrals;

P_i - load, applied to free – choice profile peak;

e - eccentricity of contact area;

$H = \left(k_1 + k_2\right)/2$ - average roughness curvature;

k_1, k_2 - roughness peak curvatures;

α - roughness peak deformation;

Θ - determined by equation $\Theta = \dfrac{1-\mu^2}{\pi E}$,

where μ - Poisson's ratio, bet E - modulus of elasticity.

Inserting in equation (1) $a_i b_i$ we obtain the following expression:

$$A_{\mathrm{el}.i} \approx \frac{\pi E(e) h_{\mathrm{el}}}{K(e)\left(1-e^2\right)^{1/2} H} \,, \tag{3}$$

where h_{el} - height of free – choice profile peak.

Assuming that the current ordinate of roughness is divided by the probability for normal distribution law, but the roughness height is divided by the Relay law it can be verified [2] that the average height mean of the elastically deformed roughness is determined by the following equation:

$$\overline{h_{el}} = \frac{\pi\left[1-\Phi(\gamma)\right]}{\exp\left(-\frac{1}{2}\gamma^2\right)} Ra \,. \tag{4}$$

Using equations (1) and (3) we can write the equation of stress for freely chosen profile peak in the following way:

$$\sigma_i = \frac{P_i \cdot K(e) \cdot \left(1-e^2\right)^{1/2} \cdot H}{\pi E(e) h_{el}} \tag{5}$$

Stress equation makes it possible to analyze the roughness deformation. Herewith, knowing the surface roughness parameters and the physical – mechanical properties of the surface roughness and by using all above mentioned equations at the given load, it is possible to determine approximation *a* by the following equation:

$$a = (\gamma_0 - \gamma) \cdot Rq \ , \tag{6}$$

where Rq - surface roughness average square deviation;

γ_0 - reference of the approximation baseline. In our case γ_0 average of the highest peak *Rt*.

γ - the relative deformation rate, defined by the equation $\gamma = \frac{u}{\sigma}$,

where u - is the distance between average plane of the roughness and position II – II of ideal plane as mentioned above, but σ - is the standard deviation in this case.

3 Conclusions

This theoretically acquired deformation is substantial component of measuring error, affected by the measured surface roughness. In this way it is acquired the potential easiest obtained processing type of the output data, comparing with some known rough surface contact theories. The experimental verification of the theoreitical calculations is planned in the near future after deterining the most suitable equipment for the task. In fact, for this time there are not a closer considered the average square deviation of surface roughness and its influencing parameters, what is a basis for further studies of roughness deformation.

References:

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