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2D AND 3D APPROACH TO MEASURING ROUGHNESS PARAMETERS

D. Indof and S. Mahovic
Faculty of Mechanical Engineering and Naval Architecture
Ivana Luèiæa 1, 10000 Zagreb, Croatia

Abstract: Contrary to the previous requirement to only monitor the changes, the need to understand the nature of the surface structure is more and more emphasised nowadays. There is already the possibility for 3D measurements, to a great extent owing to the development of electronics and computers. The contribution of this paper is in the analysis of the assessment of roughness using classical roughness parameters applied to 3D surfaces and an attempt to define the new parameters that would provide a more complete assessment of roughness with relation to the functional requirements met by the surface.
Keywords: surface characterisation, 3D roughness parameters

1 INTRODUCTION

The development of the method of contact and probe electronic and mechanical instruments has played a significant role in defining surface roughness parameters in standardisation. It may be stated that today in the world unique standards have been established regarding the definition of roughness parameters and the testing methods which are completely adapted to the method of contact and probe electronic and mechanical instruments. Defining of unique standards, based on ISO standards, has provided one of the important prerequisites for developing unity of measurement in this field.

2 2D APPROACH TO MEASURING ROUGHNESS

ISO standards, which have been as a rule directly accepted by the majority of countries, have included up to now the following segments in the field of testing surface roughness:

- terminology and definition of roughness parameters,
- instruments for testing roughness of engineering surfaces,
- working standard of roughness,
- standards for visual comparison.

The engineering surface used to be characterised by measurements along the tested profile in two dimensions (2D), using roughness measuring instruments with probe. This profile was used to define one-dimensional parameters. These parameters may be vertical, horizontal or hybrid. Great number of parameters is the result of the fact that it is not possible to define the three-dimensional surfaces unambiguously by one-dimensional parameters.

This problem is somewhat reduced by introducing hybrid parameters, although this does not solve the problem completely.

3 THEORETICAL 2D AND 3D MODELS FOR DETERMINING ROUGHNESS PARAMETERS

Due to the increasingly complex technical requirements regarding the condition of surface micro-geometry and the development of new manufacturing technologies and the introduction of high-speed machining, the classical method of evaluating the surface roughness condition is not satisfactory. The problem is primarily in surfaces machined by unconventional techniques, which usually have very strict requirements regarding the surface condition (electronic industry, medicine). Thus, the emphasis is on the need to understand the nature of the surface structure, and not, as before, only on the requirement to monitor the changes.

This has resulted in a completely new field, the 3D testing of the surface roughness condition.

The possibility of 3D measurements already exists today and to a great extent thanks to the development of electronics and computers, i.e. measuring equipment for roughness testing which makes such measurements possible. The defining of new 3D parameters is in the research phase.

In order to determine the roughness parameters it is necessary to determine the mathematical reference which can be used to measure the roughness parameters, the reference plane. For this purpose a plane would be suitable parallel to the geometric surface set in such a way through the effective surface that the mean square deviation of the surface from it is minimal. Reference plane is the size of the square *"lxl"*, whose length and width are comparable, equal to the reference length (Figure 1).

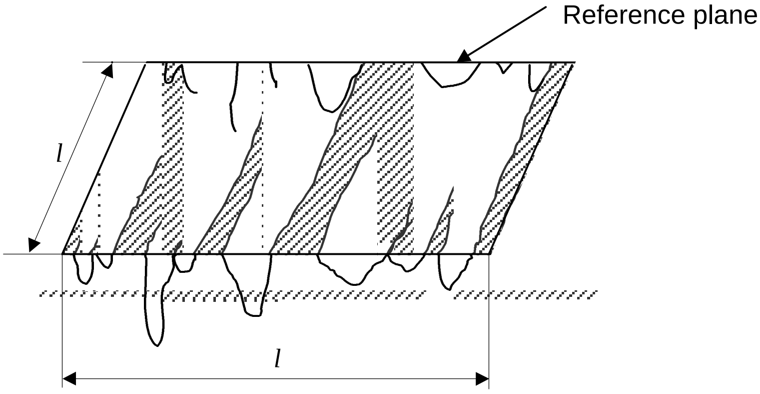
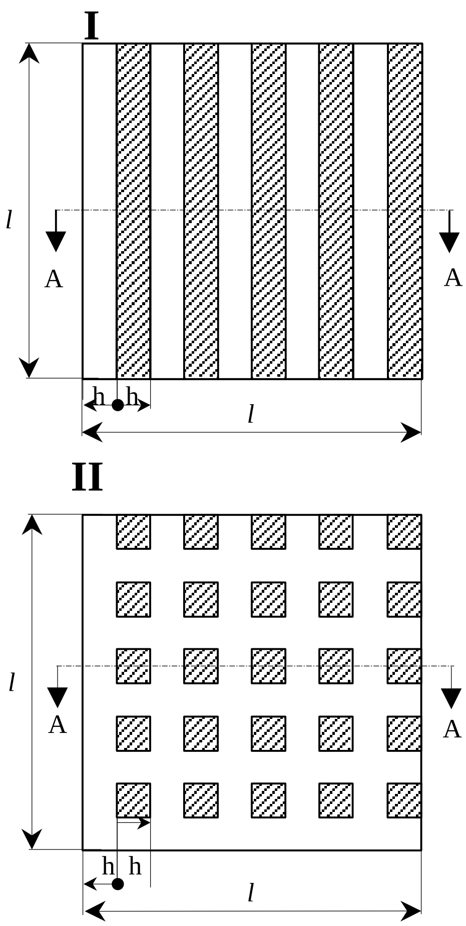
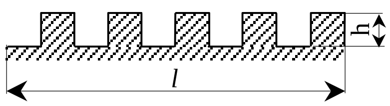


Figure 1. Reference plane



Profile A - A



Surface profile	R_a	R_p	R_y
I and II	0,5h	0,5h	h

Surface	R_a	R_p	R_y
I	0,5h	0,5h	h
II	0,375h	0,75h	h

Profile A - A

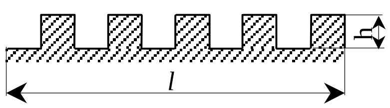


Figure 2. Comparison of 2D and 3D approach to roughness measurement – profile section: squares

Reference plane is defined by the following expressions:

$$Ax + By + Cz + D = 0 \tag{1}$$

$$a = -\frac{A}{C}, b = -\frac{B}{C}, c = -\frac{D}{C} \tag{2}$$

$$\hat{z}_i = a\hat{x}_i + b\hat{y}_i + c + e_i \tag{3}$$

$$\sum e_i^2 \longrightarrow \min . \tag{4}$$

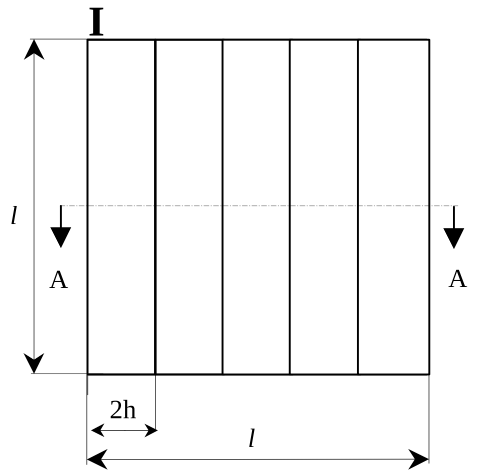
$$\frac{\partial \sum e_i^2}{\partial a} = 0, \frac{\partial \sum e_i^2}{\partial b} = 0, \frac{\partial \sum e_i^2}{\partial c} = 0 \tag{5}$$

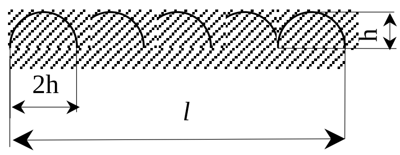
$$d_i = \frac{Ax_i + By_i + Cz_i + D}{-\operatorname{sgn} D \left(A^2 + B^2 + C^2\right)^{1/2}} \tag{6}$$

After having defined the reference plane in this way, it is possible to measure roughness parameters.

With the aim of indicating the differences between 2D and 3D approach, the characteristic theoretical surface models were used to determine the following roughness parameters: R_a, R_p and R_y. Further, the definitions of these parameters in 3D system are stated.

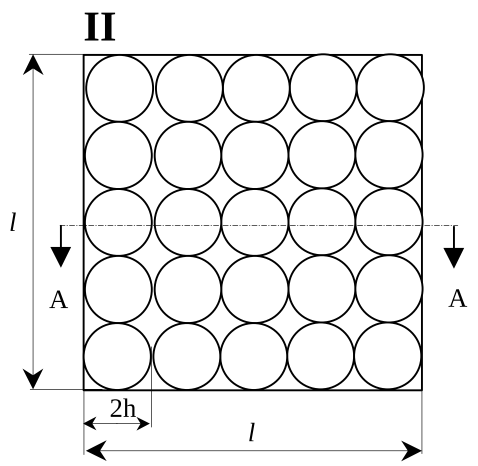
Arithmetical mean deviation of the assessed surface "R_A" equals the height of the rectangular parallelepiped whose base equals the reference plane *"lxl"*, and its volume equals the volume below the effective surface and reference plane if the elements below the reference plane are rotated by 180º.





Surface profile	R_a	R_p	R_y
I and II	0,182h	0,215h	h

Surface	R_a	R_p	R_y
I	0,182h	0,215h	h
II	0,299h	0,476h	h



Profile A - A

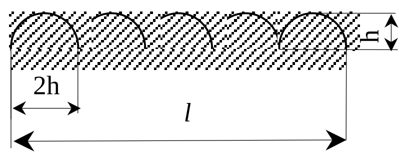


Figure 3. Comparison of 2D and 3D approach to roughness measurement – profile section: protruded rounded grooves

$$R_A = \frac{1}{M \cdot N} \sum_{j=1}^{N} \sum_{i=1}^{M} \left| d_{i,j} \right| \tag{7}$$

where:

M – is the number of points per profile,
N – is the number of profiles,
δ – is the distance of the point from the plane.

Maximum surface peak height R_P is defined as the distance between the reference plane and the plane which is parallel with it and passes through the highest point of the effective plane.

Maximum height of the surface R_Y is defined as the distance between two planes set parallel to the reference plane so that within the boundaries of the reference plane they are in contact with the highest i.e. lowest point of the effective surface.

For better understanding of the problem of evaluating surface roughness by one-dimensional parameters on the profile or on the surface, the values of these parameters have been calculated for theoretical surface models shown in Figures 2 and 3. Such theoretical models have been selected which have equal 2D profiles both in the case of directed and in the case of non-directed traces. Figure 2 represents two surface models whose profile consists of protruded squares, whereas Figure 3 shows surface models whose profile consists of protruded rounded grooves.

The obtained values of roughness parameters on the surface models with directed traces, regardless of whether they are calculated on a 2D profile or on 3D surface, are completely equal.

For non-directed traces the values of parameters are different when calculated on 3D surface or the related 2D profile.

This difference indicates the need to develop 3D roughness measurements.

4 PROBLEM OF DISTINGUISHING ROUGHNESS FROM WAVINESS ON 3D MODEL

The 3D model shows the same problem of the need to distinguish waviness from roughness as on a 2D model. This problem on the 2D model has been solved by using electric filters. Two main filters have been standardised, 2RC and the digital phase-correction filter (GS).

Within the scope of this paper, the distinguishing of waviness from roughness has been attempted by dividing the overall tested surface into a greater number of partial segments thus forming a network of *"lxl"* square surfaces (Figure 4). Using the before mentioned method, reference plane is determined for each of these surface segments, and the reference planes are connected by developing a polynomial into a unique surface which presents waviness. On this surface it is possible to determine the parameters which present deviations from waviness.

Roughness parameters are determined for each segment separately, whereas average value of parameters obtained for individual surface segments is given for the overall surface.

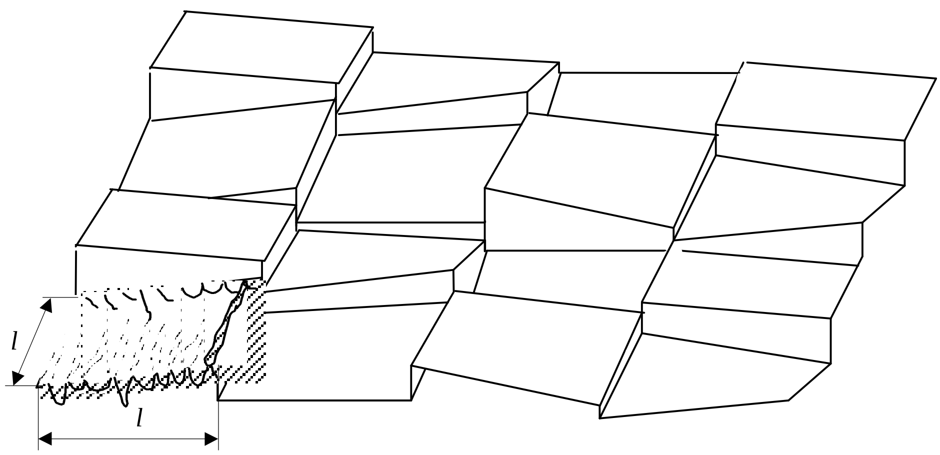


Figure 4. Distinguishing waviness from roughness by creating a network of *"l´ l"* square surfaces

5 CONCLUSION

This paper indicates the basic problems that occur in quantifying the surface roughness using a 3D model.

Technical conditions for monitoring the deviations in 3D models have been developed today. Therefore it is possible to solve the problems of distinguishing waviness from roughness by using the existing possibilities. As a result, it is suggested that the distinguishing of roughness from waviness may be solved by dividing the surface into segments and by connecting them by a polynomial into a unique surface which presents waviness. This allows roughness and waviness parameters to be determined.

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AUTHORS: D. INDOF and S. MAHOVIÆ, Faculty of Mechanical Engineering and Naval Architecture, Ivana Luèiæa 1, 10000 Zagreb, Croatia