PREDICTION OF STYLUS TIP RADIUS

Sławomir Górka, Paweł Pawlus

Abstract: *The existing method of stylus tip radius prediction was analysed. Computer generated and measured stochastic surfaces were the objects of the investigations. The effects of various sources of errors on tip radius prediction accuracy were analysed. On-line skid existence doesn't affect this accuracy, but quantisation errors caused some problems. The application of low-pass digital filtering in order to eliminate high-frequency noise was analysed.*

Keywords: *surface topography; roughness; stylus measurement; tip radius*

ACM Classification Keywords: *J.2 Physical Sciences And Engineering; G.1.2 Approximation; G.1.3 Numerical Linear Algebra;*

Introduction

Operational properties, like materials contact, sealing, friction, lubricant retention and wear resistance are related to surface topography. Stylus measurement is the most commonly used for surface topography measurement. The stylus tip has finite dimension (radius of curvature of 2, 5 or 10 micrometers). The mechanical filtering behaviour of tip depends on not penetrating irregularities of wavelengths smaller than its radius. The increase of spherical tip size causes profile distortion (decrease of the Rq parameter and increase of the RSm parameter) [Whitehouse, 1974].

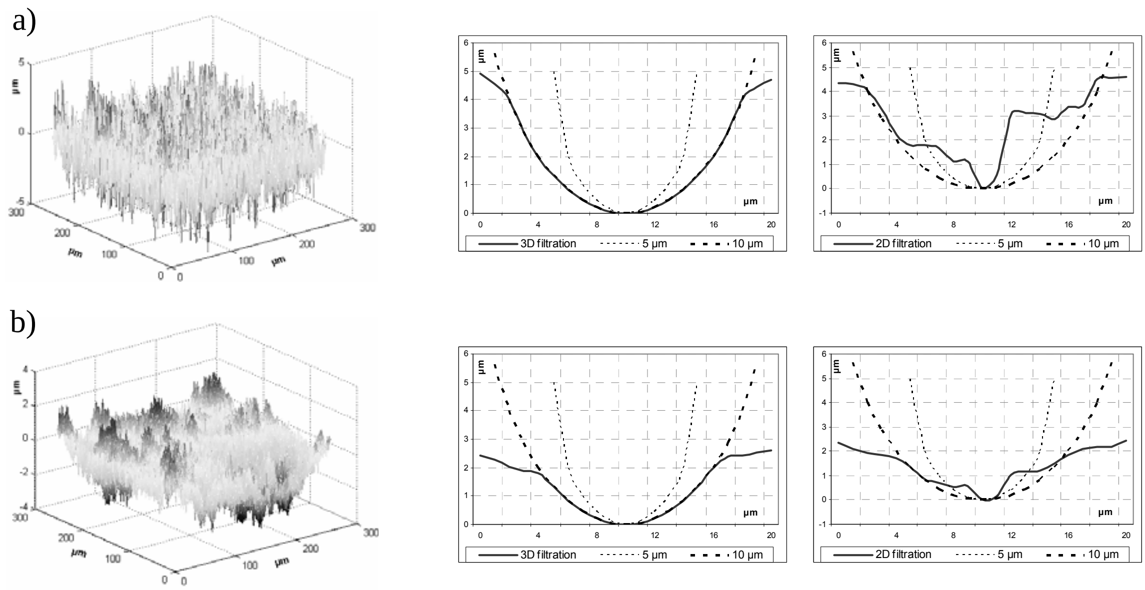

Figure 1. The isometric views (left graphs) of surfaces subjected to mechanical filtration and the shapes of reconstructed stylus tip in measurement direction after using 3D ball (middle graphs) and 2D wheel (right graphs), a) isotropic surface, b) anisotropic surface

Due to large distortion of profile, the scientists try to reconstruct of measured surface. However the surface reconstruction can be done only when the tip geometry is known. Usually the mathematical morphology erosion (lower envelope) operation was applied [Villarubia, 1994; Villarubia, 1997].

However the profile analysis can lead to correct reconstructed tip shape when anisotropic unidirectional surface is measured perpendicularly to main texture direction (across the lay). When measurement direction is different and isotropic surface is measured the errors of tip reconstruction basing only on the profile analysis can be great. Figure 1 presents the views of the anisotropic and isotropic surfaces subjected to mechanical filtration by the 3D spherical stylus and the shapes of the stylus tip in the measurement direction after reconstruction by 3D ball and 2D wheel [Górka, 2006].

The authors of paper [Dongmo, 1996] presented method of the radius of tip estimation. It depends on an erosion (lower envelope) following by a dilation making of image when radius of modelled tip "r" increases. Erosion followed by dilation is called an opening procedure. The difference between the open image and the experimental image can be assessed repeating the opening procedure, for various r values and calculating the differences and allows to fix the upper limit for the effective tip radius (see Figure 2). The special software was implemented by the authors of this paper. The effect of various errors on tip radius reconstruction was studied.

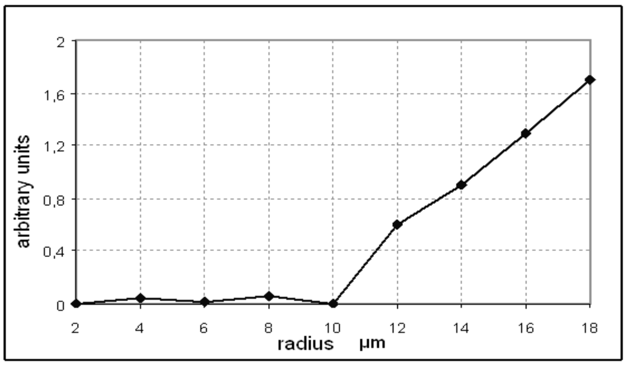

Figure 2. Plots of differences between open and dilated (measured) profiles

Results and discussion

Firstly, the analysis of simulated profiles will be done. The computer generated profiles by the present author were subjected to simulated mechanical filtering by 2D wheels of commonly used radii (2, 5 and 10 µm). In the majority of cases it was possible to obtain correct results. Figure 3 shows example of plot of differences. The radius of simulated stylus tip was 10 µm. The negligible effect of on-line skid usage on profile distortion independently on the skid radius was found.

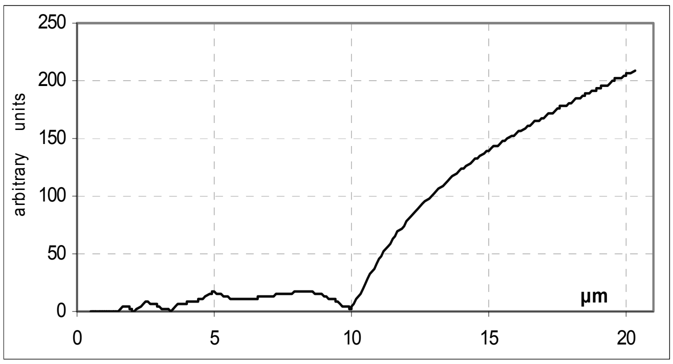

Figure 3. Plots of differences between open and dilated (measured) profile

The influence of quantisation errors on the stylus tip radius reconstruction accuracy was analysed. This error caused lift of the difference graph. Often the small number of amplitude levels was sufficient to correct tip radius estimation (50-100). Figure 4 presents example of the effect of quantisation errors on total difference graph.

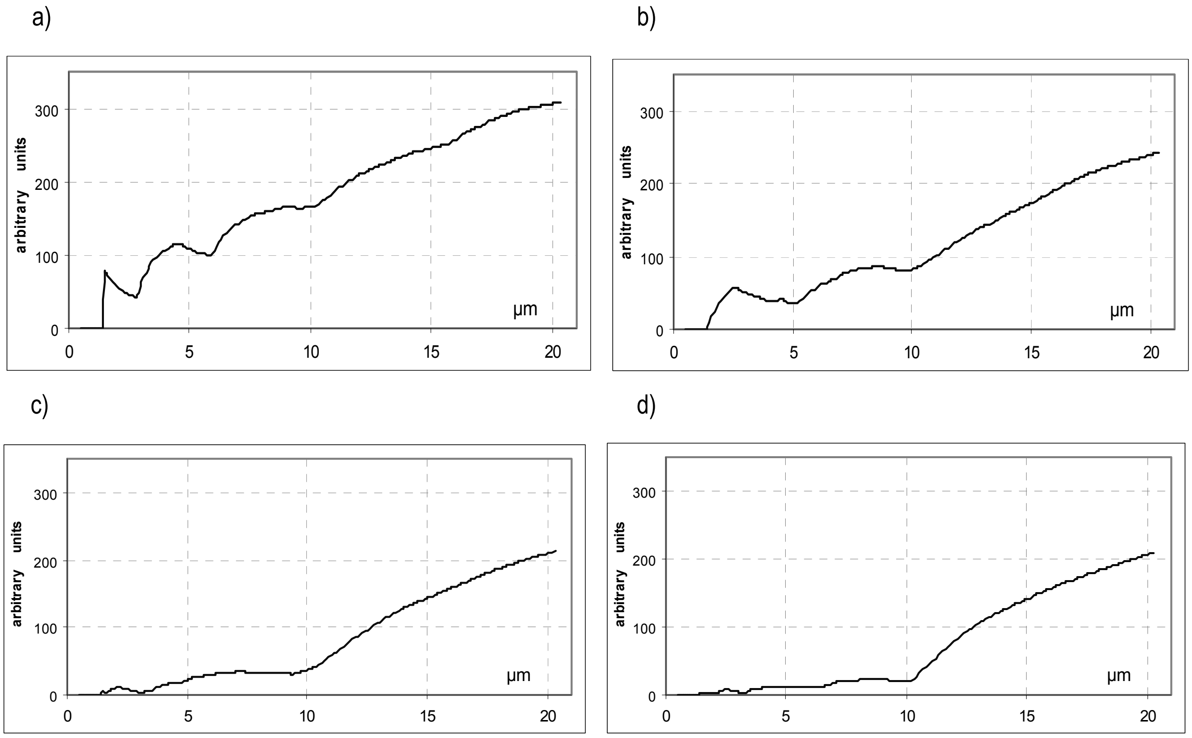

Figure 4. Plots of differences between open and dilated (measured) profiles for 10 (a), 20 (b), 50 (c) and 100 (d) height levels

The computer generated high-frequency noise was added to profiles after modelled mechanical filtration. This procedure also caused the lift of graphs, of character different to the changes caused by quantisation errors. Often the existence of high-frequency noise allowed to correct estimate of the tip radius. Figure 5 presents the effect of high-frequency noise existence on the shape of difference graph. Connection of profiles prior to tip radius estimation can be helpful.

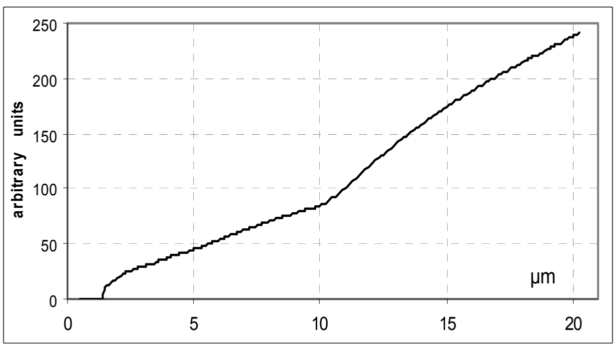

Figure 5. Plot of the difference between open and dilated (measured) profile for high-frequency noise existence

The high-frequency noise effect can be decreased by low-pass digital filtration if the main wavelength of noise is lower than tip radius. Cut-off of filter should be smaller than tip radius. For example when the main wavelength of noise was small and the tip radius was 10 µm after when the cut-off was selected precisely low-pass filtering can improve the accuracy of the tip radius estimation.

The tip radius was predicted in the measurement direction when surface topography was measured across the lay. In order to obtain precisely tip radius one should plot tangents of the two linear parts of the obtained curve searching for the point of their crossing. However often it is difficult to achieve straight lines fragments. Connect profiles is the better possibility. The results improvement is then very possible. Figure 6 presents the example of results obtained using this method.

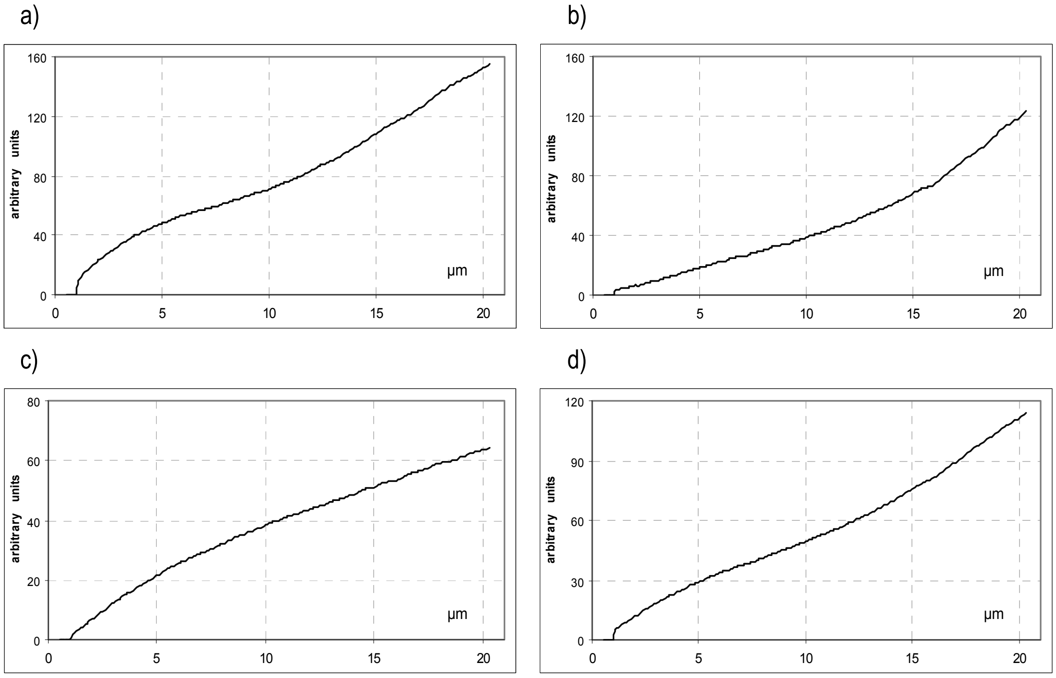

Figure 6. Plots of the differences between open and measured profiles (a, b, c) and connected profile (d). Probe tip of radius was 10 µm

This method can be further improved by using the low-pass short wavelength digital Gaussian filter. After the noise elimination the curve moves down. The results can be improved after profile connections. The results concerning the profiles which difference plots were presented in Figure 6 are shown in Figure 7.

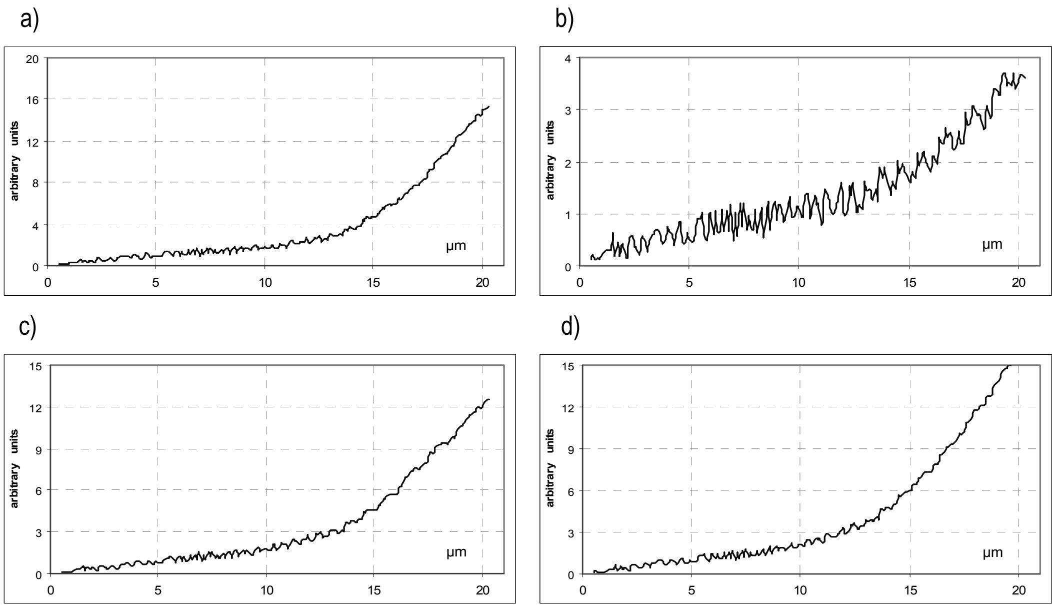

Figure 7. Plots of the differences between open and measured profiles (a, b, c) and connected profile (d) when low-pass digital Gaussian filter was used (cut-off was 10 µm)

Conclusions

The application of the analysed methods of stylus tip probe radius estimation leads to proper results. This method seems to be robust. On-line skid doesn't affect the accuracy of the tip radius prediction. However quantisation errors caused tip estimation difficulties. The use of low-pass digital frequency filtration can be the method of high-frequency noise elimination. It should be used when the noise main wavelength is smaller than the probe tip size. The connection of the profiles causes improvement of stylus tip radius estimation.

Bibliography

[Whitehouse, 1974] D. J. Whitehouse. Theoretical analysis of stylus integration CIRP Annals 23/1 1974 181-182

[Villarubia, 1994] J.S. Villarubia. Morphological estimation of tip geometry for scanned probe microscopy Surface Science, 1994 321 287-300

[Villarubia, 1997] J.S. Villarubia. Algorithms of scanned probe microscope image simulation, surface reconstruction, and tip estimation. J.Res. Natl. Stand. Technol., 1997 102 425-454

[Górka, 2006] S. Górka. The effect of measuring errors on accuracy of surface topography represebtetion. PhD Thesis, Rzeszów University of Technology, 2006, Rzeszów

[Dongmo, 1996] S. Dongmo, M. Troyon, P. Vautrot. Blind restoration method of scanning tunneling and atomic force microscopy images J. Vac. Sci. Technol, 1996 B14(2) 1552-1556

Authors' Information

Sławomir Górka *– PhD, Rzeszów University of Technology, Department of Computer Science; W. Pola 2, 35-959 Rzeszów, Poland ; e-mail: sgorka@prz.edu.pl*

Paweł Pawlus *– Associate professor, DSc, Rzeszów University of Technology, Department of Manufacturing Technology and Production Organisation; W. Pola 2, 35-959 Rzeszów, Poland ; e-mail: ppawlus@prz.rzeszow.pl*