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PROBLEMS OF SURFACE ROUGHNESS MEASUREMENT WITH A FOCUS ON THE SCANNED POINTS

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Abstract

Article deals with a important topic of evaluation of critical surface integrity parameters. Nowadays, surface integrity, especially ruggedness with a very current situation, is present, because in high performance industries such as aviation or automotive, more emphasis is still placed on shape accuracy and accuracy, but experimentally it has been found that even the correct roughness, plays a big role. Surface quality has a decisive impact on the life of critical parts for these types of industry. Article analyzes the effect of the number of points on the measured surface roughness value. The paper summarizes the results from the experimental verification of the influence of the number of points on the measured surface roughness values on selected standard pieces.

Keywords: roughness; roughness standard; distance between points; stylus

1. Introduction

Measurement and evaluation of surface texture have seen major qualitative advances in recent years. Leading producers of measuring instruments (Hommel, Carl Zeiss, and others) have responded actively to new requirements. Surface texture is frequently checked by means of single-purpose measuring instruments. For this reason, some of the key players who put pressure on developing standards related to evaluating the quality of measurement of machined surfaces are the manufacturers of such instruments themselves. [2] This has ultimately led to improved technologies of existing tools for surface texture measurement and evaluation, as well as to better methods, measuring systems and the system of assessment and evaluation of surface texture that are still under development. [6], [7] The system of assessment and evaluation of surface texture is defined by a body of standards which describe designations, measurement, and evaluation of surface texture, calibration of measuring instruments, and other aspects. They are the GPS (Geometrical Product Specification) standards. [5] Generally, the measurement and assessment of surface texture represents a separate field of metrology. Using special techniques, the data required for characterizing the quality of surface can be obtained. In order to assess the surface quality in an objective manner, relevant information on the surface in question must be obtained by measuring. First, the primary profile must be scanned using a stylus tip. From this profile, individual sets of irregularities are then filtered out (roughness, waviness, form of the surface) which comprise the actual surface texture.

These irregularities differ predominantly in their spacing and their effects on the surface performance. This is why they must be separated for analysis. [3], [8] Components of the surface texture are separated by filtering. In order to determine specific roughness parameters (Ra, Rz and others) from the measured profile (primary profile) of the surface, the roughness component must be separated from other types of irregularities found in the surface. However, when roughness is measured by a contact method, such as in this case, data distortion (filtering) by the probe arm. However, not only choice of the tip size to evaluate the roughness of the surface (Article 14) affects the resulting value. The distance between the sensed points during measurement is also significant, as describe this article.

The motivation for this article was to verify the accuracy of the machine settings when measuring surface roughness. This test is part of an extensive project to set up a software filter selection methodology for measuring surface roughness. This is solved in the framework of research at the University of West Bohemia. It verified the settings of the machine in terms of the number of points used for measuring the primary profile. The number of points was expressed and varied through spacing between points. The spacing values were as follows:

0.1 µm, which is the minimum spacing available in Hommel Etamic T 8000
0.2 µm
0.3 µm
0.5 µm, which is the recommended maximum spacing according to ISO 4288
0.7 µm
1 µm
2 µm

The test consisted of several stages. In the first one, a series of trial measurement cycles were performed at a speed of 0.1 mm/s with all the above-specified spacings. 16 measurement cycles were run in the centre of each measurement standard (Figure 1). Roughness parameters (Ra, Rz, Rv, Rsm,…) were then evaluated for all the cycles.

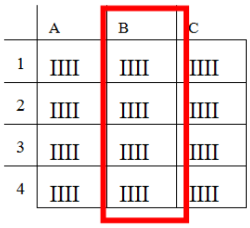


Fig. 1. Measurement cycle layout in the test [6]

However, making actual measurements with all the software filters would be very time consuming and susceptible to gross error. Therefore, a faster and simpler way was sought for obtaining the data. Generating the values by means of MS Excel software emerged as an appropriate variant. A data-thinning macro in MS Excel was used for deleting rows in a table, based on a pre-set value. The resulting primary profile data were exported into a text file and then used for surface roughness evaluation. However, the fitness of the macro and correctness of the generated data had to be verified before full deployment. The verification was performed for RA 1 and RA 6.3 standards. The test involved comparing the averages of measured roughness parameters for three spacings between points.

Measured parameter	Value from measurement I	Value from measurement II	Value from measurement III	Value from generation I	Value from generation II	Value from generation III
Ra	1	1	1	1	1	1
Rz	3.64875	3.596875	3.5757	3.601316	3.517744	3.62576
Rv	1.8131	1.789375	1.7641	1.773212	1.776849	1.716469
Rsm	3.8236	3.7420	3.752	3.773893	3.659676	3.691968

Table 1. Summary of measured and generated values - RA 1 standard

Measured parameter	Value from measurement I	Value from measurement II	Value from measurement III	Value from generation I	Value from generation II	Value from generation III
Ra	6.233	6.235	6.238	6.220534	6.22253	6.200572
Rz	23.775	23.763	23.6518	23.63235	23.16893	23.32067
Rv	11.654	11.634	11.557	11.49084	11.47112	11.53389
Rsm	0.365	0.365	0.365	0.355875	0.36281	0.355875

Table 2. Summary of measured and generated values - RA 6.3 standard

The spacing in the first cycle was 0.1 μm (value from measurement I), in the second, it was 0.5 μm (value from measurement II), and 2 μm in the third cycle. In each case, a constant measuring speed of 0.1 mm/s, a 4.8-mm path and filter 16610-21 were used. The results are given in Tables 1 and 2.[5] The largest difference between the measured and generated data was 2.7% for the Rv parameter, which makes a negligible deviation in this test.

After verifying the MS Excel macros and functions for data generation, thinned data were generated for all four standards. Thinning was applied to data measured at 0.1mm/s speed along a path of 4.8 mm with a spacing between points of 0.1 μm and with a particular filter in each case. [9], [11] During processing, a suspicion arose of an "alias surface". An "alias surface" is a surface which is created by post-processing of measured points and does not correspond to the real surface. The "alias surface" was examined on a preview of measured and evaluated profile from the Hommel Etamic T 8000 software, as shown in Figures 2 and 3.

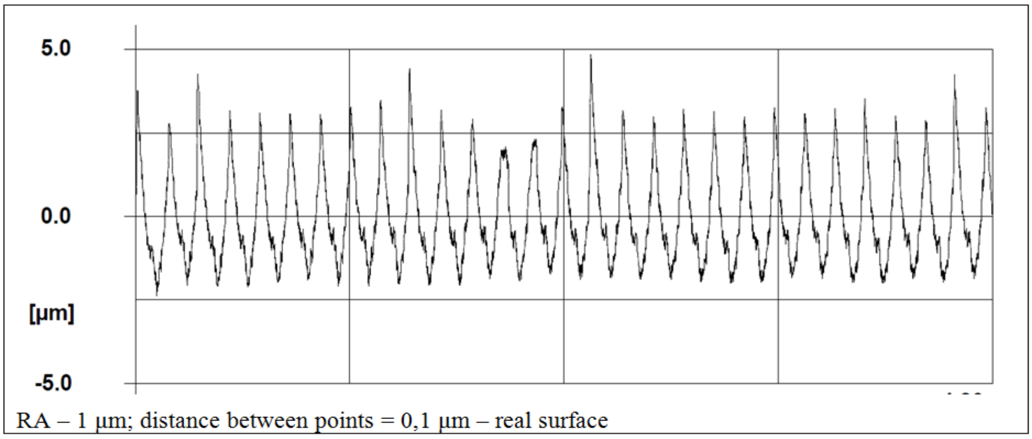


Fig. 2. 2D view of surface structure – 0.1 μm spacing [14]

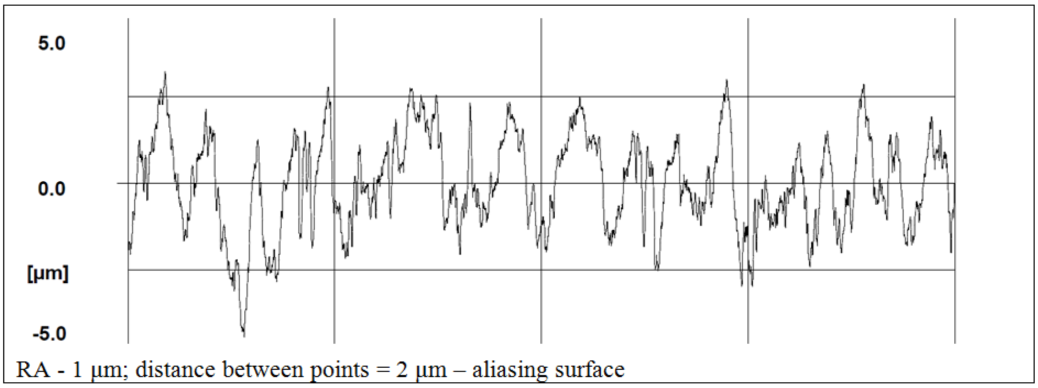


Fig. 3. 2D view of surface structure – 2 μm spacing – alias surface [14]

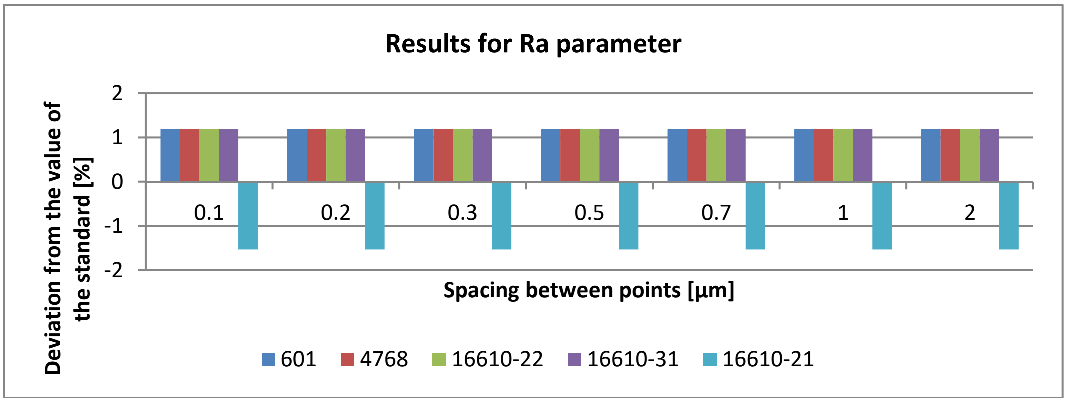
Based on these findings, the spacing of 2 μm was excluded from evaluation. It was confirmed that an alias surface is obtained with this spacing, but not with smaller spacings.

2. Results for RA 1 standard

The test was evaluated in two steps. In the first step, the average of measured values of selected roughness parameters was calculated. Its deviation from the standard's value was calculated as a percentage. In the second step, the variances of selected roughness parameters were calculated.

2.1. Results for RA 1 standard – Ra parameter

The response of the measured values to changing numbers of points was evaluated for the RA 1 standard and the full set of software filters under test. As in the test of stylus selection, this evaluation comprised four groups, each for one roughness parameter. The first was the Ra parameter. As Graph 1 shows, there are no differences between the results, apart from the 16610-21 filter. Again, the VDA rule was used for evaluation. Graph 1. shows that with the VDA rule, the optimal filter for the RA 1 standard and the Ra parameter is 16610-21.

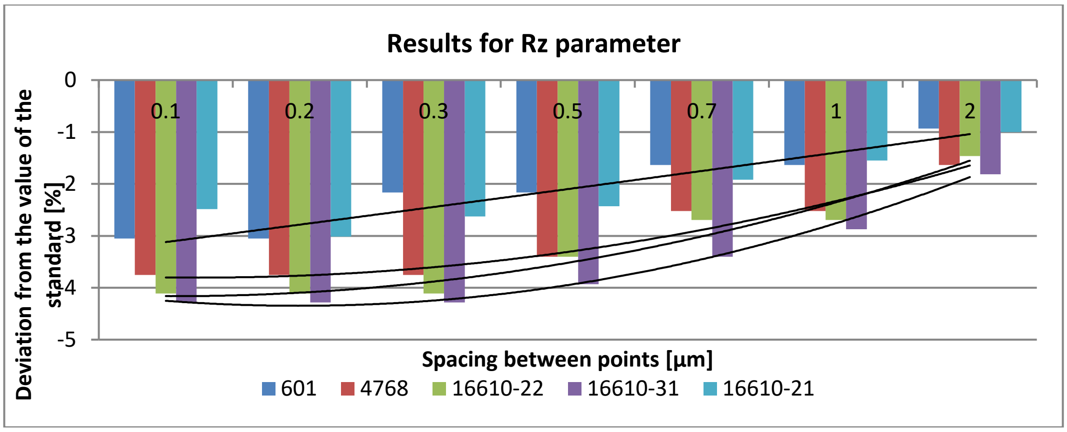


Graph 1. Average percentage deviations for the Ra parameter and RA 1 standard

As described above, this test was evaluated in two steps. The graph of variance for measured values of the Ra parameter is not included. It provides no additional information, as it mirrors the comparison between average percentage deviations. Hence, the variance comparison, too, identifies 16610-21 as the optimal filter for the Ra parameter.

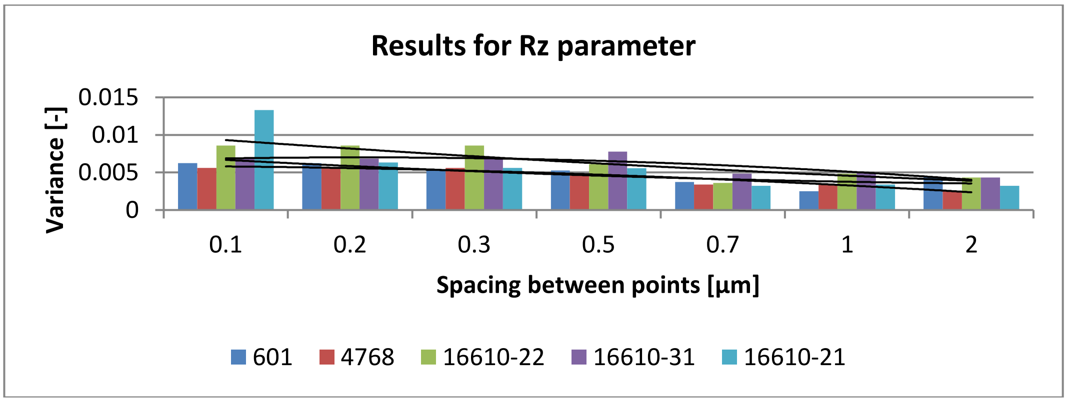
2.2. Results for RA 1 standard – Rz parameter

The Rz parameter was the first one to actually exhibit the expected trend in the measured data – with all software filters. With increasing spacing between the points, the measured value decreases. Graph 2 shows similar trends for all filters, where only the deviations from the standard were changing. An evaluation according to VDA rule identified 16610-31 as the optimal filter for this roughness parameter.



Graph 2. Average percentage deviations for Rz parameter and RA 1 standard

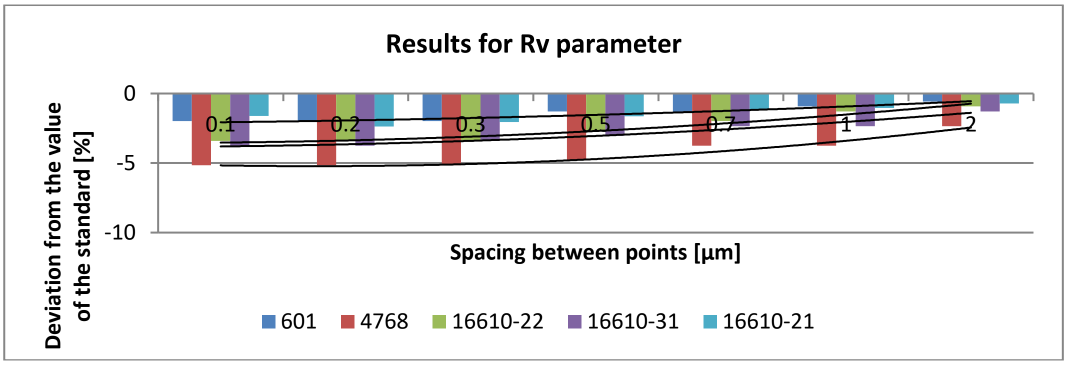
Graph 3 shows that the variance in the values of the Rz parameter decreases with increasing spacing. Based on variance comparison, the optimal filter appears to be 16610-21, except for the shortest spacing, where it is the 4768 filter.



Graph 3. Variance for Rz parameter and RA 1 standard

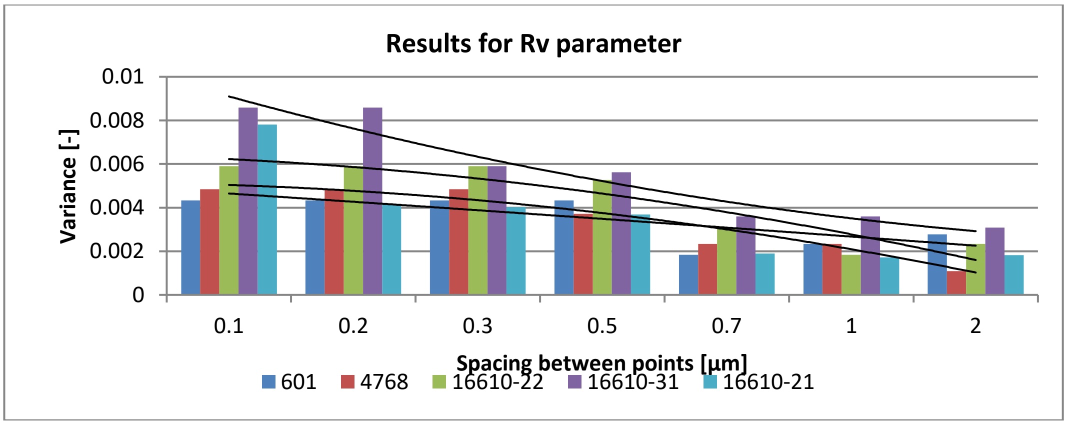
2.3. Results for RA 1 standard – Rv parameter

As with Rz, the Rv parameter confirms the expected trend: the measured value will decrease with increasing spacing between points. Whereas the best choice for Rz is 16610-31, the optimum for Rv appears to be the 4768 filter, based on the VDA rule.



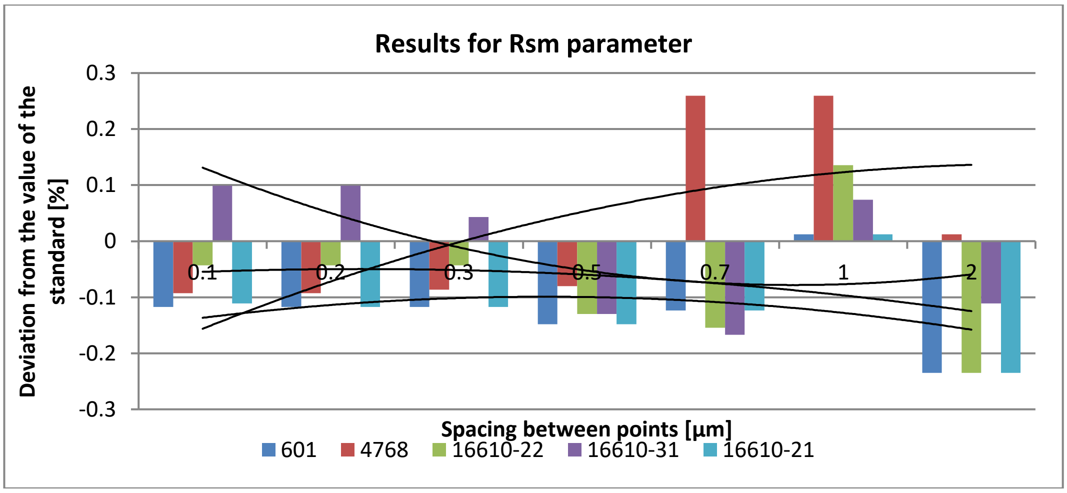
Graph 4. Average percentage deviations for Rv parameter and RA 1 standard

As Rz and Rv belong to the same group of roughness parameters, their trends and effects were expected to be the same. Yet, a difference was found, as documented by the evaluation of average percentage deviations. Graph 4 shows decreasing variance of measured values for Rv parameter. In contrast to Rz, the optimal choice for Rv appears to be the 0601 filter, when the VDA rule is applied.



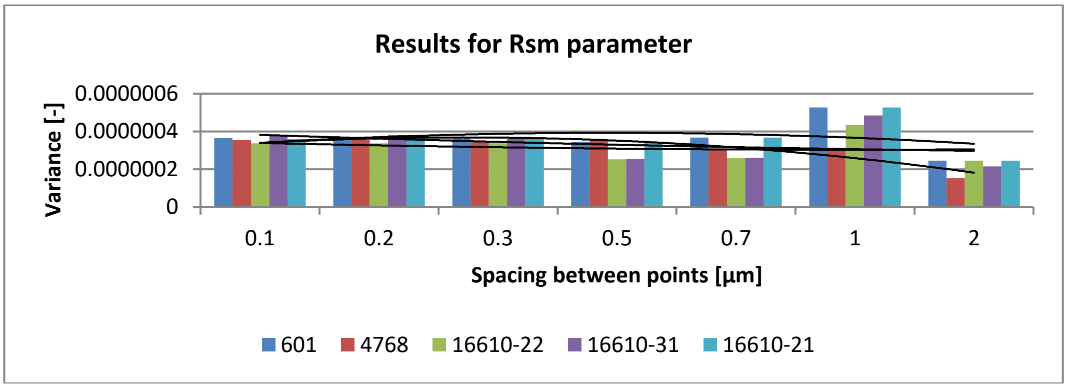
Graph 5. Variance for Rv parameter and RA 1 standard

2.4. Results for RA 1 standard – Rsm parameter



Graph 6. Average percentage deviations for Rsm parameter and RA 1 standard

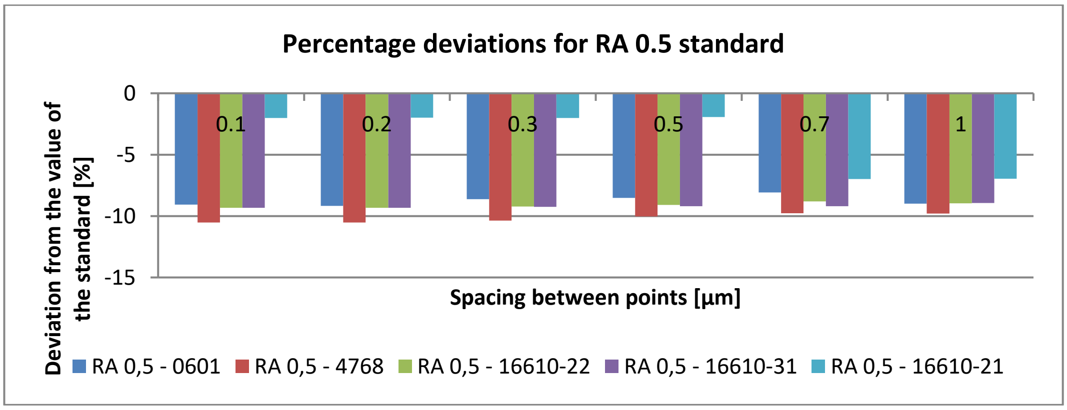
Graph 6 refers to Rsm: up to a spacing of 0.5 μm, the results were almost identical. That spacing is the maximum recommended value according to ISO 4288. The only exception related to the 16610-31 filter. The roughness number measured with this filter was profoundly different from others. Based on Graph 6, the optimum filter for Rsm parameter evaluated on the standard with a nominal value of RA 1 was 16610-21. The variance of values decreased in this case as well. The best choice appeared to be the 16610-22 filter.



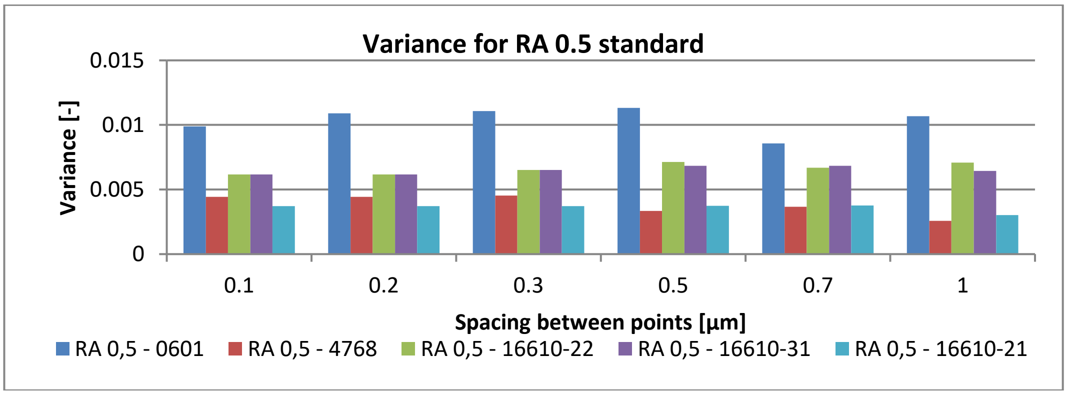
Graph 7. Variance for Rsm parameter and RA 1 standard

3. Results for RA 0.5; RA 1; RA 3.2 and RA 6.3 standards

The same evaluation as above was performed on all the other roughness standards. Roughness parameters were always measured and evaluated using a single measurement cycle. Therefore, the summary results have not been evaluated for separate roughness parameters. Instead, they were summarized as average values for each roughness standard and software filter under test. The first one was the RA 0.5 standard. A summary of data for a particular software filters and spacing converted into percentage values is shown in Graph 7. Here, the choice of the optimal variant depends on how roughness is evaluated. Up to this point, only the VDA rule was considered. However, the selection of software filters also needs to reflect the evaluation by the 16% rule.

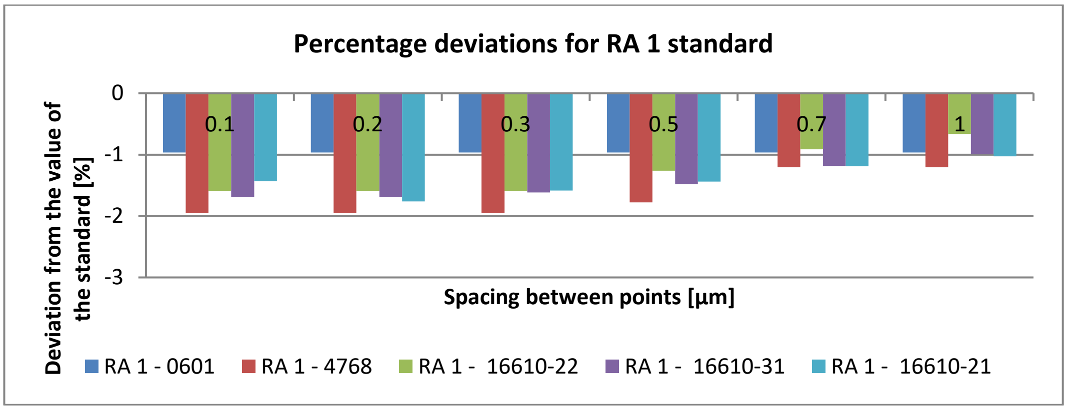


Graph 8. Summary of average percentage deviations for RA 0.5 standard



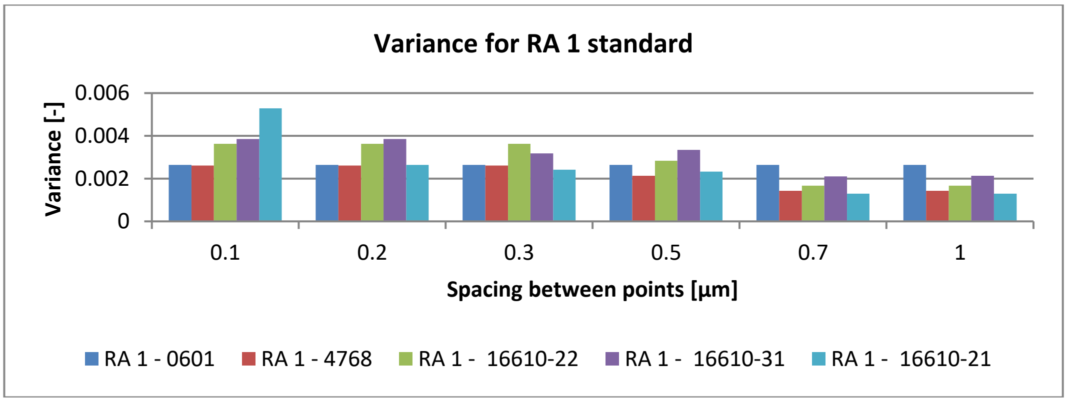
Graph 9. Summary of average variances for RA 0.5 standard

For the RA 0.5 standard, the optimal filter is 4768, when evaluated according to the VDA rule. Maximum measured values are obtained at the spacing of 0.3 µm. With the 16% rule, the optimal filter appears to be the 16610-21 filter at the spacing of 0.5 µm. An assessment based on variance of measured values yields as the optimum the 4768 filter and the spacing of 1 µm. Results for the RA 1 standard confirm the expectation that measured values would decrease with increasing spacing. As evidenced by Graph 10, an evaluation based on the maximum measured value identifies filter 4768 as the optimum choice for spacings below 0.3 µm. When the 16% rule is used, the optimal filter is 16610-21, at the 0.2 µm spacing.



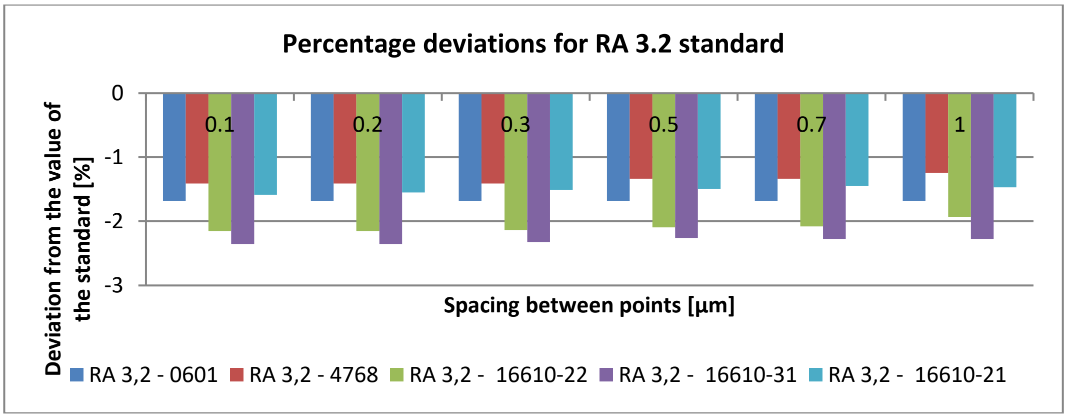
Graph 10. Summary of average percentage deviations for RA 1 standard

A variance-based assessment identifies filter 4768 and spacing of 1 µm as the optimum, see Graph 11.



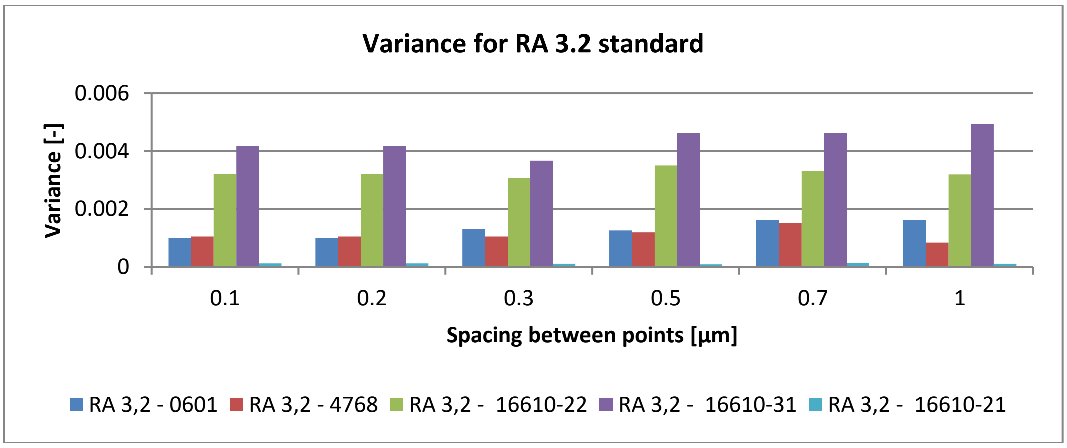
Graph 11. Summary of average variances for RA 1 standard

With increasing roughness, the effects of the spacing between points weaken, as seen in Graph 11 for RA 3.2 standard. This graph also shows that an assessment on the basis of the maximum measured value reveals 16610-21 as the optimal filter, almost equally for all spacings under test. With the 16% rule, the optimal filter is the 4768 type, whose measured value is almost identical for all spacings under test.



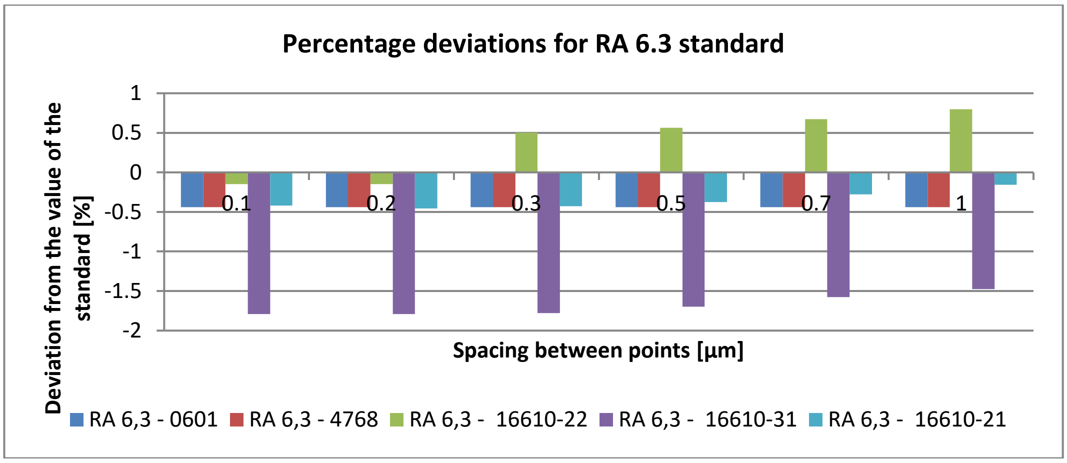
Graph 12. Summary of average percentage deviations for RA 3.2 standard

For the RA 3.2 standard evaluated using the variance of measured values, the optimum appears to the 16610-21 filter, regardless of the spacing.



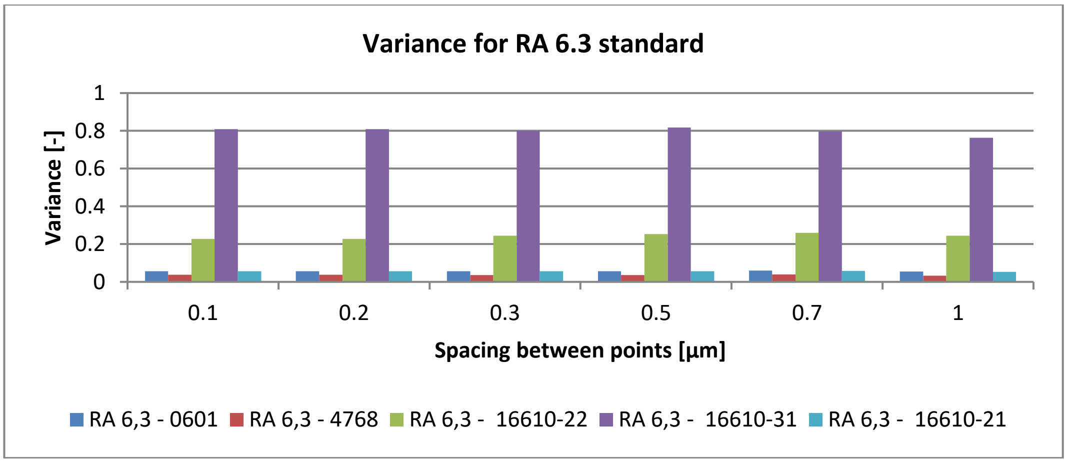
Graph 13. Summary of average variances for RA 3.2 standard

With the RA 6.3 standard, it was confirmed again that with increasing roughness, the effects of the spacing between points weaken, as seen in Graph 13. This graph also shows that an assessment on the basis of the maximum measured value identifies 16610-31 as the optimal filter, almost equally for all spacings under test. With the 16% rule, the optimal filter is the 16610-21 type, whose measured value is almost identical for all spacings under test.



Graph 14. Summary of average percentage deviations for RA 6.3 standard

For the RA 6.3 standard evaluated using the variance of measured values, the optimum appears to be the 4768 filter.



Graph 15. Summary of average variances for RA 3.2 standard

4. Conclusion

The purpose of this article was to map next small part of this field. The paper describes the problem of the setting of the roughness meter before measuring the roughness of the surface.The main objective was to point out the possible difference between the allowed distance of the points from the ČSN EN ISO 3274:1998 standard and the real optimal distance values of the points in the surface measurement and evaluation. The results of this research will be further used and implemented in the design of methods for this lection of software filters for roughness measurement.

The tests were carried out using the Hommel Etamic T8000 machine housed at the Regional Technological Institute affiliatedat the University of West Bohemia. For the testing was used stylus with diametr of tip 2 μm, with antip angle of 90°. Surface roughness standards were chosen as the test surface at nominal values RA = 0.5 μm; RA =1 μm; RA =3.2 μm and RA =6.3 μm. On each standard were made 16 waveform executed in the central part of etalon. The scanning speed that was used, was set to the smallest possible 0,1 mm/s. The test point distances were chosen: 0.1 μm (the smallest value used to dilute the data), the other values were: 0.2 μm; 0.3 μm; 0.5 μm; 0.7 μm; 1 μm and 2 μm. The whole test was performed with one software filter, namely Gauss filter ČSN EN ISO 16610-21:1998.

The data were evaluated in several steps. First test was made, because the data was calculated using MS Excel, where data was diluted as needed, as would be the case with repeated measurements on the machine. In MS Excel we was working with one primary profile, which was only diluted, it was ensured that data from one primary profile was still working and the error was not attributable to the error due to the different surface structure on the roughness surface (surface errors were obvious). And due to the importance role of the MS Excel, it was necessary to verify the proper functioning of this dilution in the first step. The correct dilution function in MS Excel was verified by comparing the data generated with the data obtained under the same conditions. Validation was performed for the RA=1μm standard. The check was carried out by comparing the average measured value of the tested roughness parameters at two points distance points. The initial measurement was with distance 0.2 μm (value obtained by measurement I) and second value was 1 μm (value obtained by measurement II). Measuring was made by use constant speed of measurement of 0.1 mm/s. The difference between measured and generated data was at a maximum of 1.7% for Rv and Rmax parameters, which is negligible in this test. And it was probably due to the impossibility of repeating (removing) the primary profile in one place.

A primary assessment of the effect of the number of points was performed on the roughness parameter Ra. This parameter was chose because this parameter is very difficult respond to changes in surface structure. And since differences in results have already been recorded on this parameter, it has been necessary to devote even more depth to this issue of point distance selection. The second part of the evaluation was performed by calculating the variance of the values for the selected distance of the points. Here, would be ideally distance between of point 2 μm,too. But since this value has already been excluded in the previous step, it is based on optimum 0.7 μm.

To verify the hypothesis that the optimal value of the distance of the points is distance between of point 0.7 μm, the evaluation was performed for other parameters, in this case for the parameter Rz. Here again, the results test were same as for parameter Ra and for the parameter Rz, the optimal point distance is 0.7 μm. Subsequently, to assure that the actual measured values are correct, a calculation of the Meter's Eligibility was performed. This calculation also estimated that, apart from the distance values of 2 μm and more, the results are irrelevant.

5. Acknowledgments

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