EVALUATION OF THE INFLUENCE OF THE NUMBER OF POINTS ON THE MEASURED

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Abstract

The paper deals with the very topical issue of evaluating the critical parameter of surface integrity. Nowadays, surface integrity measurement, especially the roughness of the surface, is extremely effective, because top production industries such as the aerospace industry or the automotive industry place the highest emphasis on the accuracy of dimensions and also on the accuracy of surface integrity. Surface quality has a decisive impact on the durability of critical parts in these industries.

The article analyses the effect of the number of points on the measured surface roughness value. In the first part of the article, the theory of the methodology is discussed. The second part of the article explores and describes an experiment in which experimental measurements and subsequent comparison with the relevant ISO standard are performed for different values of roughness measurements and different numbers of points. In the last chapter, the results are evaluated and compared. There is a slight deviation of about 20% from the ISO standard.

Keywords: *roughness, roughness standard, distance between points, stylus*

1. INTRODUCTION

The 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 putting 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 systems 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 known as the GPS (Geometrical Product Specification) standards. [5]

The measurement and assessment of surface texture is a field of metrology. Using special techniques, the data required for characterizing the quality of a surface can be obtained.

In order to assess 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 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 on the surface. When roughness is measured by a contact method, such as in this case, data is distorted (filtered) by the probe arm. The resulting value for evaluating the roughness of the surface is not only affected by the choice of the tip size (Article 14), the distance between the points during measurement is also significant, as is described in this article.

2. MEASUREMENT OF SURFACE ROUGHNESS BY CONTACT METHOD

The ČSN EN ISO 3274:1998 standard defines a contact instrument as a measuring instrument which explores surfaces with a stylus and acquires deviations in the form of a surface profile, calculates parameters and can record this profile. One of the important components of the instrument is the measurement loop. It is a closed chain which comprises all the mechanical components that connect the work piece and the stylus tip.

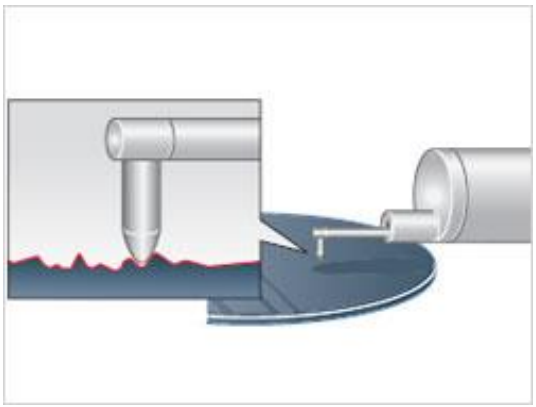


Fig. 1 Roughness measuring [3]

The accuracy of the measurement reading is influenced by the following:

- stylus tip radius
- stylus tip apex angle
- measuring (loading) force
- number of scoring points
- rate of change of measuring force

This article describes the effect of the number of measured points for evaluating roughness parameters. This area is often neglected when setting a machine before measuring. The maximum allowed value of the distance between the points specified in EN ISO 3274:1998 is very often used for setting up the machine for measuring. Fig. 2 shows what happens if the incorrect distance between points is used during measuring. The evaluated surface may be negatively affected, creating an aliasing surface. Even large numbers of points are not optimal, because this extends the measuring time, leading to a very heavy workload with a huge amount of data to be processed.

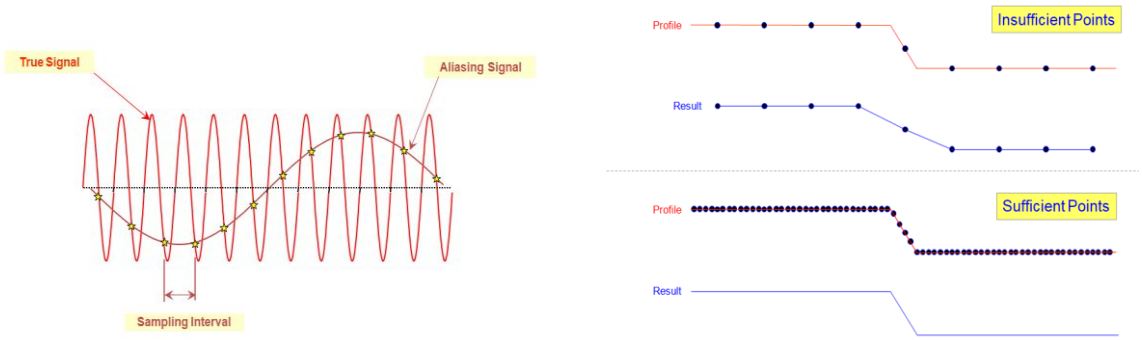


Fig. 2 Difference between numbers of points [3]

By scanning a small number of points, the primary profile is distorted, but scanning a large number of points is not ideal either. So, how to determine the optimal number of points for measuring roughness? This experiment was carried out to solve this question. The experiment was performed in several steps and levels of testing. The article describes an experiment using one type of software roughness filter. The distance between the measured points and the size of the value of surface roughness were changed during the experiment.

3. EXPERIMENT

The experiment was performed on a Hommel Etamic T8000 profilometer. A stylus with a diameter of 2 µm and a tip angle of 90° was used for the reasons described in (article 15), which deals with this issue.

The lowest speed possible to set on the machine was used – 0.1 mm/s, and the distances between the points were: 0.1; 0.2; 0.3; 0.5; 0.7; 1 and 2 µm. The distances between points of 0.7, 1 and 2 µm were tested, although they exceed the maximum distances for the lower roughness values that is given by standard ČSN EN ISO 3274:1998. It was assumed when planning the experiment that the size of roughness to be tested would include not only small sizes of roughness but also higher values of surface roughness that are allowed for these values.

Roughness standards with nominal values of RA 0.5 µm; RA 1 µm; RA 3.2 µm and RA 6.3 µm were chosen as the tested roughness samples.

Prior to measurement, each reference standard was divided into 10×6 mm fields (Fig. 3). Only data from column B was used for this test. Using data from column B prevents errors from being introduced into the measurements due to the imperfections in the roughness standards. The paths were arranged not to overlap, which was made possible by the machine's high precision measuring table. After the standard had been installed in the required position, its movements were carried out exclusively by the measuring table. All measurement runs were repeated twice. The pattern of measuring paths started 0.5 mm from the edge of the field. Each subsequent path was spaced 1 mm from the previous one (0.5; 1.5; 2.5; …).

	A	B	C
1	IIII	IIII	IIII
2	IIII	IIII	IIII
3	IIII	IIII	IIII
4	IIII	IIII	IIII

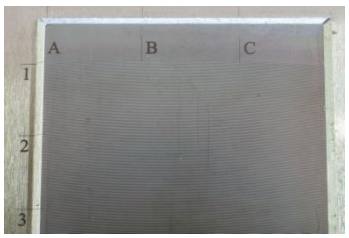


Fig. 3 Segmentation of the standard

In this test, a wide range of roughness parameters relating to all fields were evaluated, including all kinds of profile parameters, roughness parameters and waviness parameters. This article only describes those parameters which are most often used in the automotive and aircraft industries. Their values were calculated using a Gaussian filter (ČSN EN ISO 16 610-21). For more detailed characteristics of this filter, see Article 14.

4. PROCESSING OF RESULTS

The test was performed and evaluated in several steps. The first step was to recalculate the data using MS Excel, where unnecessary rows were deleted and the measured data was diluted out as would be the case with repeated measurements on the machine. MS Excel helped to speed up data processing for

the required point spacing and also ensured that it was still working with data from one primary, and that any errors were not attribut able to errors caused by different surface structures (obvious errors on the surface).[7,12,13]

4.1. Verification of accuracy of MS Excel

The correct dilution function in MS Excel was verified by comparing the data generated by MS Excel with the data obtained by measuring. The same conditions were used for comparison. Validation was performed for the roughness standard with RA 1μm. The check was carried out by comparing the average measured value of the tested roughness parameters at two point distances. The initial measurement was with point distance 0.2 μm (value obtained from measurement I) and for the second measurement it was 1 μm (value obtained from measurement II). All measurements were made at a constant rate of 0.1 mm/s. The difference between the measured and generated data was a maximum of 1.7% for roughness parameters Rv and Rmax, which is negligible in this test.[9,11] This was probably caused by the impossibility of repeating (measuring) the primary profile in one place.

Measured parameter	Value obtained by measurement I	Value obtained by measurement II	Value obtained by calculating I	Value obtained by calculating II
Ra	1.0275	1.0271	1.0275	1.0271
Rz	3.64875	3.596875	3.6478	3.5967
Rv	1.8131	1.789375	1.0808	1.7845
Rmax	3.82	3.74	3.8096	3.7299

Table 1. Table of values to verify the accuracy of the MS Excel dilution function

Subsequently, after verifying that data generation using macros and functions in MS Excel works, data were generated for all 4 standards in the above dilution. Data dilution was always carried out on the measured data at 0.1 mm/s and a point distance of 0.1 μm, and the Gauss filter was used as the software filter (16 610-21).

4.2. Evaluation of test for parameter Ra

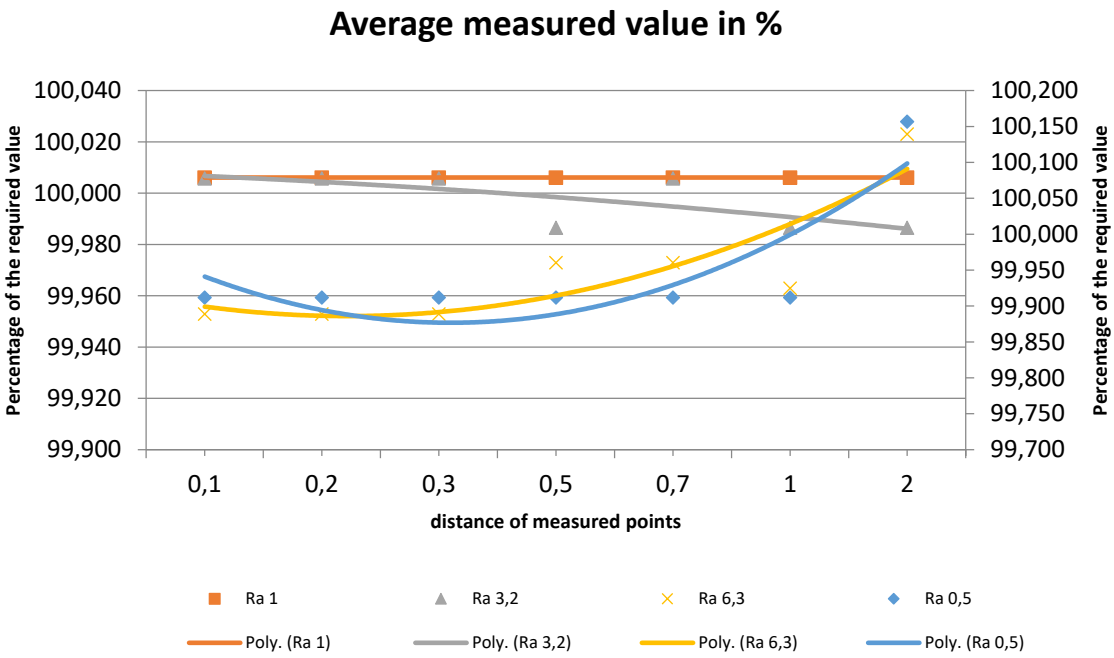
4.2.1. Average measured values

16 repetitions of measuring were performed in the middle of each roughness standard, as described in Chapter 3. This is enough to use statistical induction for the behaviour of the measured data [11].

The first step in evaluating the influence of the number of points on the measured roughness was to compare the average of the measured data and determine its trend. This is shown in Graph 1. Because of the need to compare data from different surface roughness values, data was converted to percentages. The number from the calibration sheet of the standard on which the test was performed was assumed to be 100%. See Table 2

		0.1	**0.2**	**0.3**	**0.5**	**0.7**	**1**	**2**
Ra 0.5	0.51045	99.912	99.912	99.912	99.912	99.912	99.912	100.157
Ra 1	1.0274375	100.006	100.006	100.006	100.006	100.006	100.006	100.006
Ra 3.2	3.2504375	100.006	100.006	100.006	99.987	100.006	99.987	99.987
Ra 6.3	6.2366875	99.953	99.953	99.953	99.973	99.973	99.963	100.023
		99.969	**99.969**	**99.969**	**99.969**	**99.974**	**99.967**	**100.043**

Table 2. Table of averaged measured values, expressed as a percentage, for roughness parameter Ra



Graph 1. Average Measured Values for Ra

Note: values on the minor axis are RA 1 roughness values

The highest percentage value from the measured averages was found during the evaluation of the measured averages, see Table 2. The highest value of the percentage averages was for point distance 2 µm, but there was a suspicion of aliasing of the surface (creating a new surface that has nothing to do with the original surface). This was confirmed by comparing the measured data in graphic form as shown in Fig. 4, and therefore the 2 µm distance point was removed from this test. For this reason, the best value in terms of the diameter of the measured data is the distance value 0.7 µm. The aliasing surface was also inspected, but the test was negative.[13,12]

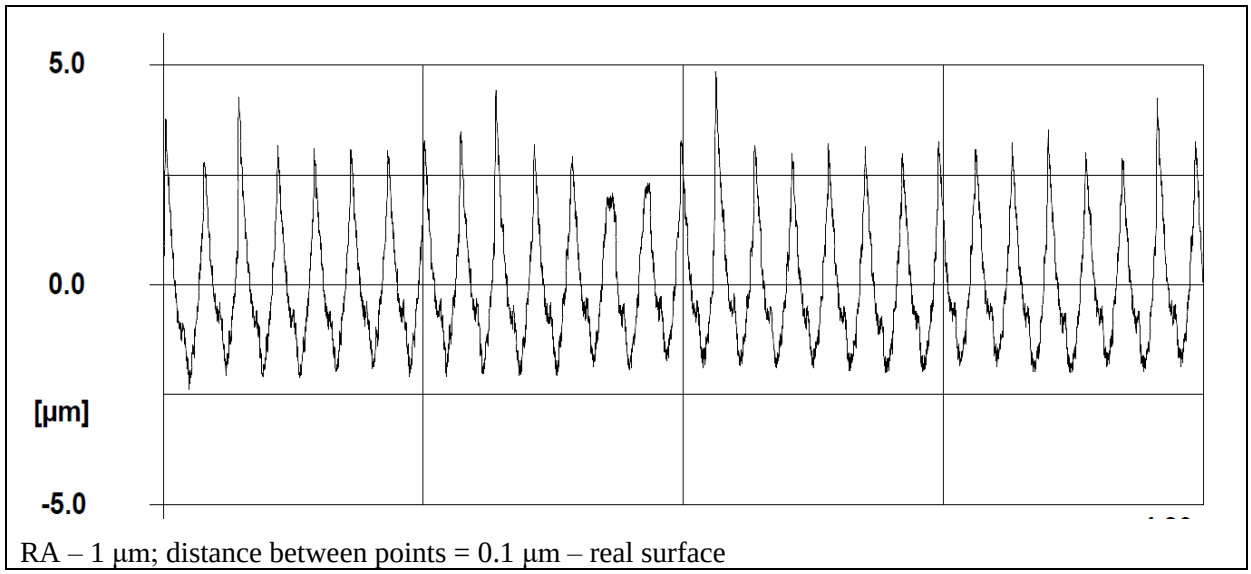


Fig. 4a. Graphic test for aliasing surface for points with distance 2 µm or more

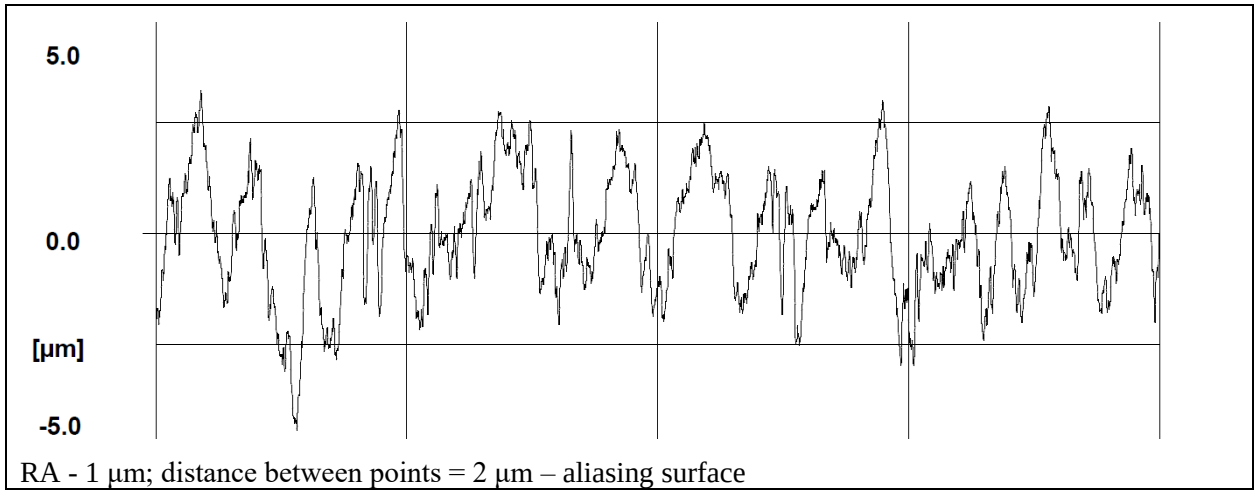


Fig. 5b. Graphic test for aliasing surface for points with distance 2 µm or more

4.2.2. Dispersion of measured values

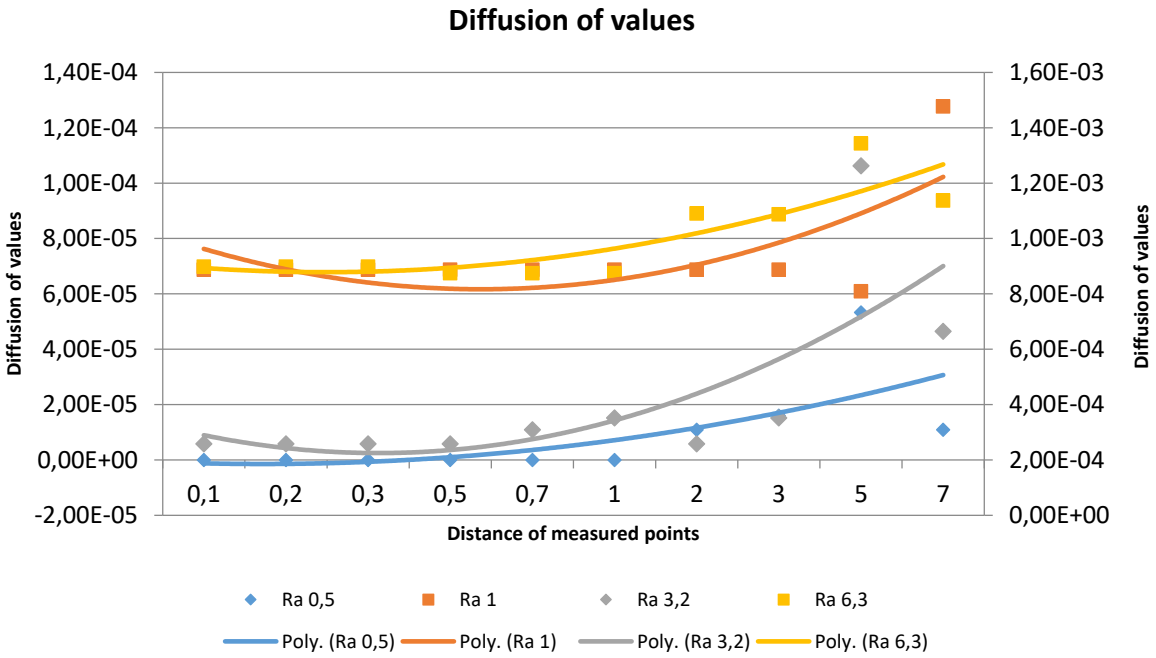
Drawing conclusions using one evaluation can be very misleading. It is always good to have conclusions based on at least two or more evaluations. Therefore, the next step in processing and achieving a particular optimum point distance value when measuring surface roughness was to carry out the evaluation based on the variance of the measured values.

Table 3 and Graph 2 summarize the results for this part of the experiment. In this part of test we looked for the lowest value of value scattering.

	0.1	**0.2**	**0.3**	**0.5**	**0.7**	**1**	**2**
Ra 0.5	1.23E-32	1.23E-32	1.23E-32	1.23E-32	1.23E-32	1.23E-32	1.09E-05
Ra 1	6.88E-05	6.88E-05	6.88E-05	6.88E-05	6.88E-05	6.88E-05	6.88E-05
Ra 3.2	5.86E-06	5.86E-06	5.86E-06	5.86E-06	1.09E-05	1.52E-05	5.86E-06
Ra 6.3	8.98E-04	8.98E-04	8.98E-04	8.75E-04	8.75E-04	8.75E-04	1.09E-03
	2.43E-04	**2.43E-04**	**2.43E-04**	**2.37E-04**	**2.49E-04**	**2.40E-04**	**2.94E-04**

Table 3. Table of variance values for the roughness parameter Ra

Even in this case, the most suitable distance is 2µm, but it is not possibleto use it due to aliasing, as described above.



Graph 2. Value scatter graph for parameter Ra

So far, the Ra parameter has been measured during the evaluation. This parameter does not have a good response to the changing surface structure. Other statistical analyses for other roughness parameters were made to check that the provisional conclusion is correct.

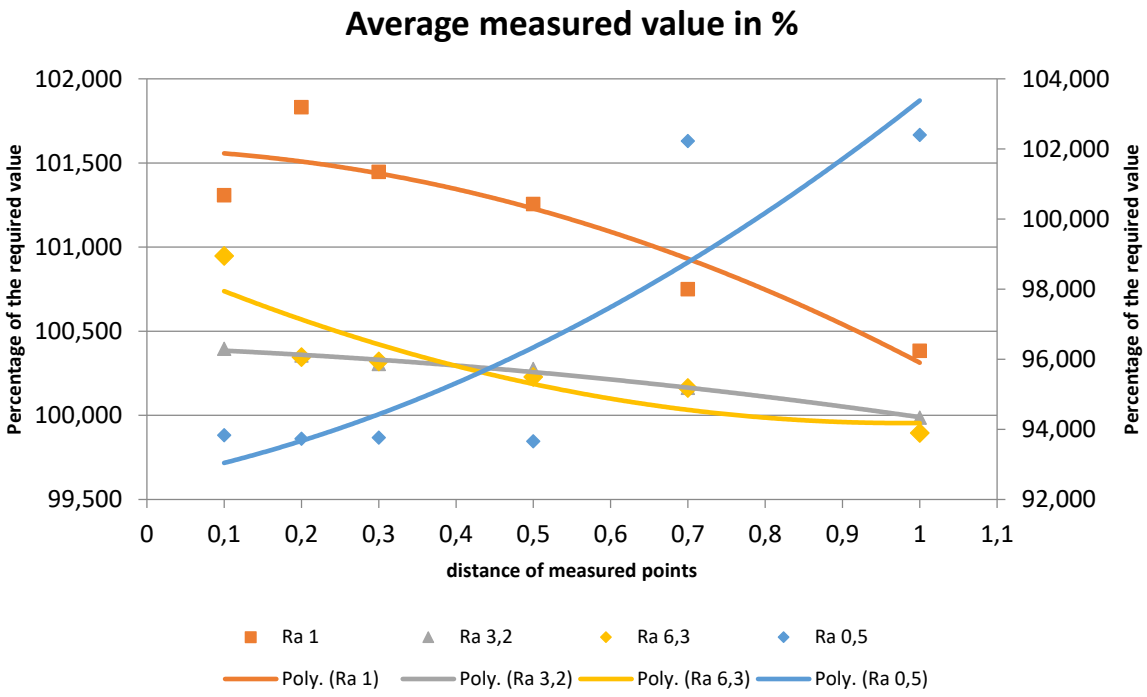
4.3. Evaluation of test for parameter Rz

4.3.1. Average measured values

The parameter Rz was evaluated in the same way as parameter Ra. This also involves recalculating the average measured values into percentages and comparing them.

		0.1	**0.2**	**0.3**	**0.5**	**0.7**	**1**
Ra 0.5	1.795	93.837	93.733	93.768	93.663	102.229	102.403
Ra 1	3.583	101.308	101.832	101.448	101.256	100.750	100.384
Ra 3.2	27.641	100.397	100.356	100.306	100.277	100.164	99.987
Ra 6.3	37.223	100.948	100.346	100.321	100.229	100.163	99.896
		99.123	**99.067**	**98.961**	**98.856**	**100.826**	**100.667**

Table 4. Table of averaged measured values expressed as a percentage for roughness Rz



Graph 3. Graph of the measured values of parameter Rz

Note: the values on the minor axis are roughness values for Ra 0.5

The highest percentage measured value from the average of the measured data was found during evaluation.

The evaluation was concerned with the highest percentual value of the measured data. Table 5 shows that the Rz column is empty for value 2. Previous testing has shown that the value 2 distorts the measurement results. The best result from the tested distances 0.1; 0.2; 0.3; 0.5; 0.7 and 1 µm were achieved with a distance of 0.7 µm.

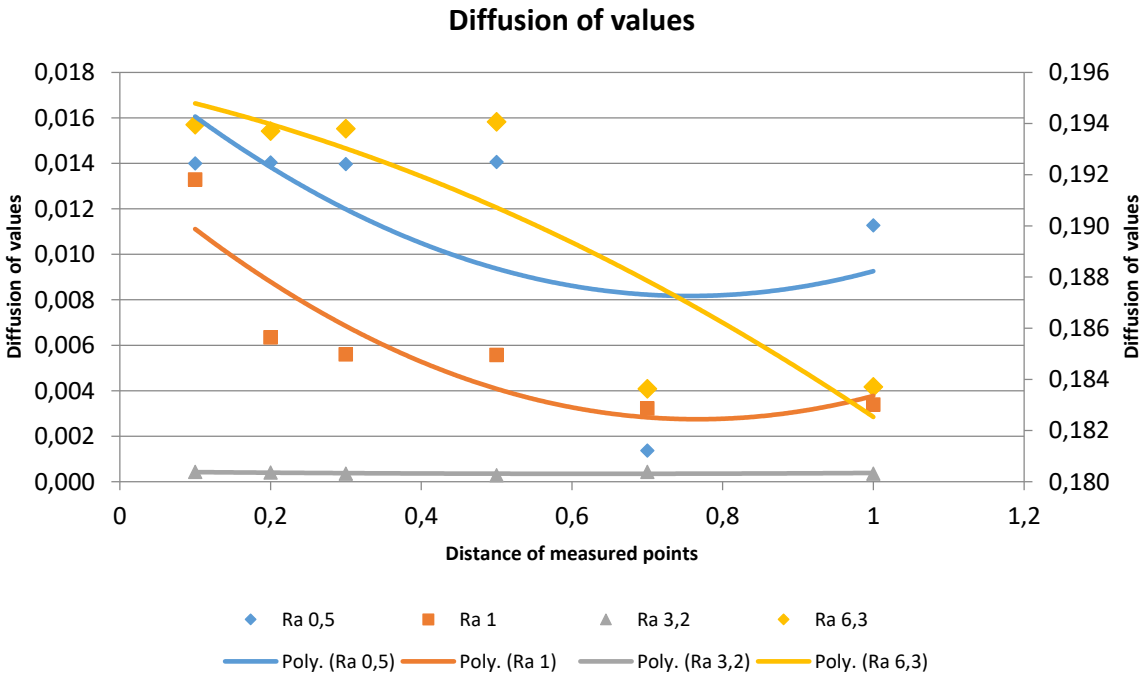
4.3.2. Dispersion of measured values

Table 5 and Graph 4 summarize the results for this part of the test. At this point, the most important data is the lowest value of dispersion. The lowest value of Rz was found.

	0.1	**0.2**	**0.3**	**0.5**	**0.7**	**1**	**2**
Ra 0.5	0.014	0.014	0.014	0.014	0.0014	0.011	
Ra 1	0.013	0.006	0.006	0.006	0.003	0.003	
Ra 3.2	0.000	0.000	0.000	0.000	0.000	0.000	
Ra 6.3	0.194	0.194	0.194	0.194	0.184	0.184	
	0.055	**0.054**	**0.053**	**0.053**	**0.047**	**0.050**	

Table 5. Table of variance of values for roughness Rz

Even here, based on previous tests, there was an omission of the point distance 2 µm. And so, as in the test for percentage expression of the mean measured values, the optimum point spacing is 0.7 µm.



Graph 4. Graph of the dispersion of values for parameter Rz

5. CONCLUSION

The demands on high-speed components are increasing, increasing the demands on measuring the geometric parameters and deviations and even the surface integrity parameters of such components. This is one of the reasons why the measurement and evaluation of surface texture has seen major qualitative advances in recent years. Leading producers of measuring instruments (Hommel, Carl Zeiss, and others) have responsed actively to these new requirements. They have done so despite the fact that surface texture is frequently measured and evaluated using single purpose measuring machines – and have developed new machines, equipment, methods, standards and guidelines.

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

The tests were carried out using the Hommel Etamic T8000 machine housed at the Regional Technological Institute at the University of West Bohemia. A stylus with tip diameter of 2 µm, and tip angle of 90° was used. Surface roughness standards were chosen for the test surfaces with nominal values RA = 0.5 µm; RA =1 µm; RA =3.2 µm and RA =6.3 µm. 16 waveforms were executed in the central part of each standard. The scanning speed was set to the smallest possible, which was 0.1 mm/s. The following 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, Gauss filter ČSN EN ISO 16610-21:1998.

The data were evaluated in several steps. The first test was done 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 worked with one primary profile, which was only diluted; we ensured that data from one primary profile was still working and any errors were not attributable to errors caused by different surface structures on the roughness surface (surface errors were obvious). And due to the

important role of 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 measured 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 point distances. The initial measurement was with distance 0.2 μm (value obtained by measurement I) and the second value was 1 μm (value obtained by measurement II). Measuring was done at a constant speed of 0.1 mm/s. The difference between the measured and generated data was a maximum of 1.7% for Rv and Rmax parameters, which is negligible in this test. This 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 chosen because it responds with great difficulty to changes in surface structure. Since the differences in the results have already been recorded for this parameter, it is necessary to study this issue of point distance selection in even greater depth.

The evaluation of the test was carried out in two steps, and then the gauge's competence was verified. In the first step, the measured values for individual point distances were averaged and converted to compare different roughness values. The value from the calibration sheet of the roughness standard was taken as 100%. Two pieces of information came from the transfer. When comparing and searching for the maximum value, the optimal distance between points was 2 μm. However, when the graphic records were examined in greater detail, it was revealed that this distance forms an aliasing surface (a surface different from our controlled surface from a standard). When the point distance of 2 μm is removed from a possible solution, a point distance of 0.7 μm emerges in this first evaluation for parameter Ra.

The second part of the evaluation was the calculation of the variance of the values for the selected distances of the points. Here, a point distance of 2 μm would be ideal too, but since this value has already been excluded in the previous step, it is based on the optimal value of 0.7 μm.

To verify the hypothesis that the optimal value of the point distance is 0.7 μm, the evaluation was performed for other parameters, in this case for parameter Rz. Here again, the results were the same as for parameter Ra and for parameter Rz, and the optimal point distance is 0.7 μm.

Subsequently, to ensure that the actual measured values are correct, the meter's eligibility was calculated. This calculation also estimated that, apart from the distance values of 2 μm and more, the results are irrelevant.

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