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Specific Aspects of Roughness Measurement

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Abstract: The article deals with problems in determining the surface roughness of parts. The arithmetic mean height of the roughness Ra is mainly monitored. This quantity is most often used when defining the required surface quality of components. Assessment of surface roughness is important in the production of parts, their assembly and their use. This article solves some problems in the process of determining this quantity.

Keywords: control system, sensor, traffic light, human machine interface.

1. Introduction

One of the possibilities of assessing the quality of the surface of the parts is to monitor the roughness of the surface, which is formed by unevenness caused by the technology of production and surface treatment. The roughness of the surface is an important feature of the surface of the parts, which must be assessed to ensure the functionality of the parts or to create surface treatments or for the aesthetic design of the parts. There are several contact or non-contact methods for assessing surface roughness. This article focuses on the contact method of assessing surface roughness using a surface tester that produces a profile curve. Surface roughness values are subsequently assessed on this profile curve. The process of obtaining the profile curve of the surface as well as the subsequent evaluation is a relatively complicated process, due to a large number of factors that influence these processes. These factories cause great variability in the evaluated data, and wrong methodology results in incorrect surface roughness assessment results [1-7]. There are a number of standards for these surface roughness assessment processes [8-15].

Individual values of surface roughness are listed in EN ISO 4287 [8] and EN ISO 5436 [11] standards, and these standards were later replaced by a set of ISO 21920-1, ISO 21920-2 and ISO 21920-3 standards [12 – 14], where individual quantities are defined and methodological guidelines for their determination and processing are given.

For a long time, individual surfaces for assessing surface roughness were categorized into two large groups, namely periodic surface roughness profiles and non-periodic surface roughness profiles. Non-periodic profiles are characterized by random addition of surface unevenness on the obtained profile curve (for example, grinding, lapping and polishing). For periodic profiles, the regular repetition of the unevenness caused by the regular engagement of the cutting tool with a certain spacing (for example, turning, milling, planing) is typical.

When assessing the quality of the surface, however, it is sometimes not known by which technology the surfaces of the parts were obtained, so the standards of the ISO 21920 series [12 – 14] introduce a non-discriminatory assessment between periodic and non-periodic surface profiles. The uniform methodology for choosing measurement parameters is no longer influenced by the production technology, which simplifies the process of assessing the quality of the surface of sub-particles.

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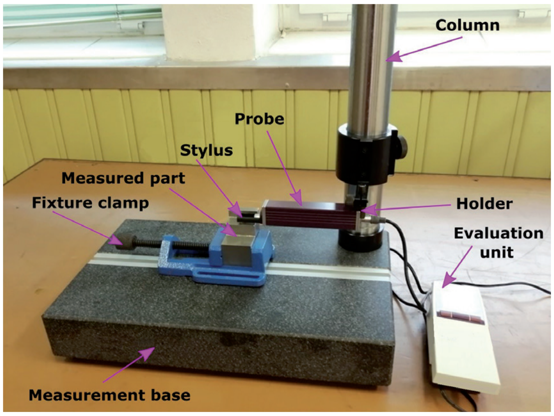

Figure 1: Surface tester with stylus tip for surface roughness evaluation.

During the measurement, the stylus tip of the surface roughness tester moves evenly across the tested surface by shear, and the sensor part then detects surface irregularities, which are later processed by the evaluation unit in the form of surface roughness values.

In this study, the focus is on the investigation of the arithmetic mean height of the roughness Ra, which is most commonly used for evaluating the surface roughness of components.

2. Influence of Parameter Settings During Measurement and Evaluation Ra

All available surface testers for determining surface roughness values allow selection of the cut-off value λc (or the text equivalent Lc), selection of the standard for evaluating surface roughness values, selection of sensing tip (stylus) speed and selection of other possible settings of measurement conditions. This fact complicates the accuracy of measuring and determining surface roughness values. Experience shows that the influence of the choice of these settings can have a rather fundamental effect on the obtained values of surface roughness quantities.

In the standards [10, 14, 15], there are certain recommendations for setting parameters for measuring and evaluating surface roughness values (Tab. 1 and 2), but these are linked to Ra values, which need to be determined by this process of measurement and evaluation. In many cases, however, we do not know the value of Ra, which should be realized on the examined surface by the prescribed technological process. The value of the quantity Ra must therefore be determined by another method in order to be able to select the Setting class (Tab. 2).

Table 1. Recommended measuring speed values for Lc (ISO11562; ISO 3274)

Cut-off λc (mm)	*Sensor feed speed (mm/s)*
0.08	0.25; 0.5
0.25	0.25; 0.5
0.8	0.25; 0.5
2.5	0.25; 0.5; 0.75

3. Experimental Determination of the Influence of Setting the Measurement Parameters and Determination of Surface Roughness Values

The significance of the influence of individual settings on the process of determining the Ra value can be determined experimentally using reference

Table 2. Setting classes - recommended settings for case of missing specification (ISO 21920-3)

Setting class Sc	*Sc1*	*Sc2*	*Sc3*	*Sc4*	*Sc5*
Parameter Ra (μm)	*Ra≤0.012*	*0.012<Ra≤0.006*	*0.06<Ra≤1.2*	*1.2<Ra≤6*	*Ra>6*
Profile L-filter nesting index Nic (cut-off λc (Lc) for R-parameters) (mm)	0.08	0.25	0.8	2.5	8
Evaluation length lm (mm)	0.4	1.25	4	12.5	40
Profile S-filter nesting index Nis (cut-off λs) (μm)	0.8	0.8	2.5	8	25
Maximum sampling interval dx (μm)	0.15	0.15	0.5	1.5	5
Maximum tip radius rtip (μm)	2	2	2	5	10
Section length lsc (mm)	0.08	0.25	0.8	2.5	8
Number of sections nsc	5	5	5	5	5

samples with known Ra values. Measurements of surface roughness were carried out at individual settings of the surface tester. The measurements were carried out at the same place but with different settings.

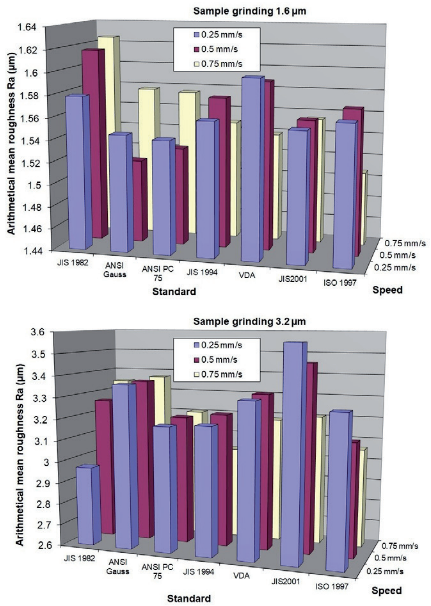

Figure 2: Values of the arithmetic mean height of the roughness Ra at different settings of the evaluation standard and speed of movement of the sensing tip.

In fig. 2 shows the influence of the set speed of the stylus measurement and the selected standard for the evaluation of the surface roughness values on the Ra value. The influence of stylus speed and selection of standard was experimentally investigated for two different samples of surface roughness (fig. 2). From this graphical representation, it can be seen that the influence of the standard and speed of the stylus is significant and cannot be neglected. The selection of the evaluation standard must be agreed with the customer who requires this measurement. The stylus speed must be selected according to table 1.

When measuring surface roughness, it is also important to assess the effect of settings on the variability of evaluated surface roughness values. Ten measurements were performed with the same settings at the same measurement location. The degree of variability expressed in percentages is shown in figure 3 for two different standard surface roughness samples. It follows from these measurements that even the selection of standard for assessing surface roughness has an impact on the evaluation results. With some standards, a significant difference in variability is visible depending on the evaluated sample. It is equally interesting to observe the influence of the stylus speed on the variability of the quantity Ra (fig. 4), where it can be seen that the variability of the values of the quantity Ra decreases with increasing stylus speed.

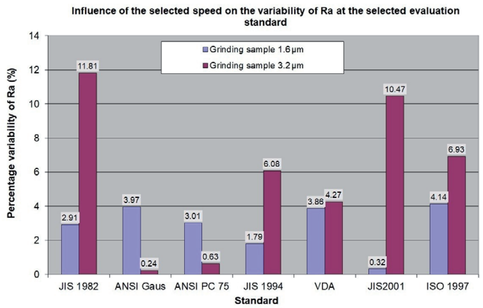

Figure 3: Variability of the arithmetic mean height of the roughness Ra at different settings of the evaluation standard during repeated measurements at the same measurement location.

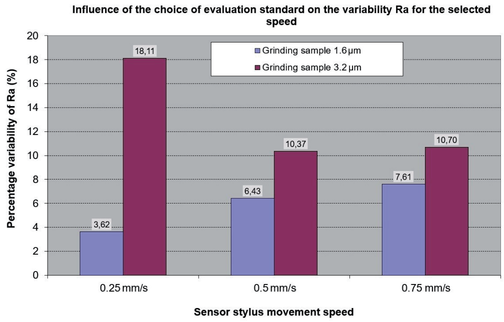

Figure 4: Variability of the arithmetic mean height of the roughness Ra at different settings of the speed of movement of the sensing tip during repeated measurements at the same measurement point.

From the point of view of the repeatability of the measurement, the question of the number of repeated measurements that will provide the value of the quantity Ra with the desired measurement uncertainty or standard deviation of the measurement. For this purpose, measurements were carried out at the same place with the number of measurements (100 of measurements), while after each carried out measurement the standard deviation was evaluated. The course of these deviations shows how this value changed for individual technologies (fig. 5).

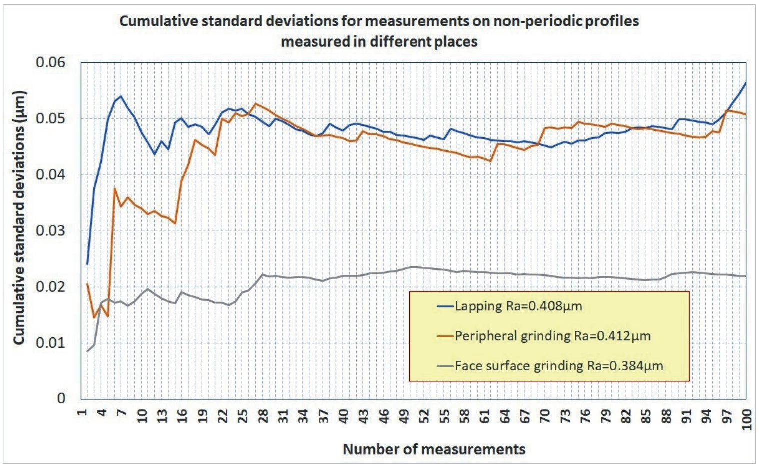

Figure 5: The standard deviation of the measurement for increasing repeated measurements at the same place under the same conditions for samples obtained by different production technologies.

This graph gives information on how many measurements need to be made. A large number of measurements increases the price of the measurement, but this graph shows the optimal number of measurements, when the standard deviation of the measurement no longer improves with the increasing number of performed measurements. From this graph (fig. 5) it follows that the optimal number of measurements is 30, because further repeated measurements do not significantly improve the value of the standard deviation and thus the uncertainty of the measurement.

4. Conclusions

The issue of surface roughness evaluation is typical in that the results of this process have a very high degree of variability and measurement uncertainty, which is largely related to the used technology for producing the surface of the part under investigation. However, the setting of the surface tester also has a great influence on the resulting uncertainty of the measurement, which was demonstrated by the experiments in this work, and therefore it is necessary to focus increased attention on these settings so that the results of the assessment of surface roughness are not degraded by inappropriate settings of the device and do not contribute to the overall uncertainty of the measurement.

It turned out that the problem is also that the choice of settings is tied to the value of the surface roughness value Ra, which in some cases cannot be determined due to the absence of drawing documentation. For this purpose, it will be appropriate to develop a methodology and equipment for the initial estimation of the surface roughness quantity Ra.

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References

1. Whitehouse, D. J.: Surfaces and Their Measurement, 1st ed., Butterworth-Heinemann, 2004. 432 pages. ISBN 9781903996607.
2. Kumar, S.P.L.: Measurement and uncertainty analysis of surface roughness and material removal rate in micro turning opera-tion and process parameters optimization, Measurement, Vol. 140, 2019; pp. 538-547, ISSN 0263-2241, https://doi.org/10.1016/j.measurement.2019.04.029.
3. Beňo, J.; Maňková, I.; Vrabel, M.; Kottfer, D.: Roughness measurement methodology for selection of tool inserts, Measurement, Vol. 46, Iss. 1, 2013; pp. 582-592, ISSN 0263-2241, https://doi.org/10.1016/j.measurement.2012.08.017.
4. Kreith, F.: The Mechanical Engineering Handbook Series. 2nd edition, CRC PRESS. New York, 2005. ISBN 0-8493-0866-6. 2508 pages.
5. Leach, R.: The Measurement of Surface Texture using Stylus Instruments. NPL National Physical Laboratory. HMSO. United Kingdom. July 2001 ISSN 1368-6550.
6. Poon, Ch. Y.; Bhushan, B.: Comparison of surface roughness measurements by stylus profiler, AFM and non-contact optical profiler, Wear, Vol. 190, Iss. 1, 1995; pp 76-88, ISSN 0043-1648, https://doi.org/10.1016/0043-1648(95)06697-7.
7. Jester, W.; Klik, A.: Soil surface roughness measurement—

methods, applicability, and surface representation, Catena, Vol. 64, Iss. 2–3, 2005; pp. 174-192, ISSN 0341-8162, https://doi.org/10.1016/j.catena.2005.08.005.

8. ISO 4287:1997 Geometrical Product Specifications (GPS) – Surface texture: Profile method – Terms, definitions and surface texture parameters. First edition 1997-04-01. International Organization for Standardization. Geneve. Switzerland.
9. ISO 4288: 1996 Geometrical Product Specifications (GPS) – Surface texture: Profile method – Rules and procedures for the assessment of surface texture. November 1997. European Committee for Standardization. Brussels. Edition DIN EN ISO 4288 : 1998-04. April 1998.
10. ISO 3274: 1996 Geometrical Product Specifications (GPS) – Surface texture: Profile method – Nominal characteristic of contact (stylus) instruments. European Committee for Standardization. Brussels. December 1996.
11. ISO 5436-1:2000 Geometrical Product Specifications (GPS) — Surface texture: Profile method; Measurement standards — Part 1: Material measures. European Committee for Standardization. Brussels. March 2000.
12. ISO 21920-1:2021 Geometrical product specifications (GPS) — Surface texture: Profile — Part 1: Indication of surface texture. European Committee for Standardization. Brussels. December 2021.
13. ISO 21920-2:2021 Geometrical product specifications (GPS) — Surface texture: Profile — Part 2: Terms, definitions and surface texture parameters. European Committee for Standardization. Brussels. December 2021.
14. ISO 21920-3:2021 Geometrical product specifications (GPS) — Surface texture: Profile — Part 3: Specification operators. European Committee for Standardization. Brussels. December 2021.
15. ISO 11562:1996 Geometrical Product Specifications (GPS) — Surface texture: Profile method — Metrological characteristics of phase correct filters. European Committee for Standardization. Brussels. December 1996.