How to cite this article:

Authors: Emilia Bachtia-Radka, Sara Dudzińska, Daniel Grochała, Stefan Berczyński

Title of article: „Influence of digital processing of milled surface measurement data on the S_q parameter”

Mechanik, No. 12 (2019)

DOI: <https://doi.org/10.17814/mechanik.2019.12.107>

Influence of digital processing of milled surface measurement data on the S_q parameter

EMILIA BACHTIAK-RADKA**SARA DUDZIŃSKA****DANIEL GROCHAŁA****STEFAN BERCZYŃSKI ***

* Mgr inż. Emilia Bachtia-Radka, ebachtia@zut.edu.pl, <https://orcid.org/0000-0003-3366-0083> – Zachodniopomorski Uniwersytet Technologiczny, Szczecin, Polska

Mgr inż. Sara Dudzińska, sara.dudzinska@zut.edu.pl, <https://orcid.org/0000-0002-2577-7899> – Zachodniopomorski Uniwersytet Technologiczny, Szczecin, Polska

Dr inż. Daniel Grochała, daniel.grochala@zut.edu.pl, <https://orcid.org/0000-0003-2553-7739> – Zachodniopomorski Uniwersytet Technologiczny, Szczecin, Polska

Prof. dr hab. inż. Stefan Berczyński, stefan.berczynski@zut.edu.pl, <https://orcid.org/0000-0002-8403-6355> – Zachodniopomorski Uniwersytet Technologiczny, Szczecin, Polska

Digital processing of recorded measurement data on the milled surface can offer operators many possibilities in the planning metrological procedures processes and give more leeway in the final configuration of the surface geometrical structure condition. Review of the current state of knowledge revolving around surface characteristics, measurement uncertainty and their quality, and primarily reproducibility of measurements not only in the laboratory but also in the industrial environment poses a major challenge. The article presents research works related to the identification of the influence of the measurement data processing method using digital data processing of milled surface on the S_q parameter. The analysis of individual stages of measurement data processing showed the direct influence of data filtration methods on the values of the S_q parameter.

KEYWORDS: digital data processing, point cloud filtration procedure, geometric structure of the surface, optical measuring systems

Introduction

Recording measurement data without errors in the shape of surface unevenness allows to opt out of digital processing of these data, so that the values of surface geometrical structure (SGP) parameters are free from random operator influence [1–3]. The methodology for determining the SGP parameter values is simpler when the assumption is made about the ideal (without shape errors) point cloud acquisition. The parameter values – without cutting out the threshold values, leveling and filtration – should be reproducible for various measuring systems and allow the classification of measuring devices [9]. Most commercial measuring devices use the phase shift effect [4] or the confocal effect of chromatic light [5–7] in their operation. Standards [4, 5, 7–9] and technical documentation of measuring devices lack detailed information on how to acquire measurement data [9–15]. Only basic rules and recommendations are given [1, 3].

In order to identify the impact of the measurement data processing method, experimental studies were carried out. The sample from X160CrMoV121 material was processed by milling and then tested on the AltiSurf A520 measuring machine located at the West Pomeranian University of Technology in Szczecin (ZUT). The measurements were carried out in accordance with the fractional experiment plan developed. It includes a strategy for processing measurement data for subsequent stages: cutting out the threshold values, leveling, removing the shape and filtering. AltiMap PREMIUM version 6.2 was used. The impact of individual data filtration methods on the value of S_q parameter, defined as the mean square deviation of surface roughness, was investigated:

$$Sq = \sqrt{\frac{1}{M \cdot N} \sum_{j=1}^N \sum_{i=1}^M \theta^2(x_i, y_j)} \quad (1)$$

where: $M \cdot N$ – size of the sampling matrix, $\theta(x_i, y_j)$ – residual surface (bearing surface).

The paper analyzes the Sq parameter, which is determined by the same algorithm as the average effective power of RMS electrical signals. This parameter effectively visualizes variability of the surface deviation from the mean plane. On its basis, it is possible to detect interference and evaluate – by filtering – the "power loss" of the signal due to too strong distortion introduced.

Research material

The surfaces of $100 \times 100 \times 20$ mm samples made of X160CrMoV121 steel and tempered (with a hardness of 2 ± 2 HRC) were tested. This material was chosen because of its use in the design of stamping dies, which were formed by milling on a DMG DMU 60 monoBLOCK machine equipped with a torus head (WNT R1000G.42.6.M16.IK) with six cutting inserts with a diameter of $d_p = 10$ mm (RD. X1003 MOT – WTN1205) at an angle of 15° to the machine axis. Other technological parameters are included in the tab. I.

TABLE I. Milling technological parameters

Cutting speed v_c , m/min	110
Depth of cut layer a_p , mm	0.5
Feed per revolution f_r , mm/rev	0.6
Milling cross feed f_{wf} , mm	0.3

Measurement methodology

The X160CrMoV121 sample was measured on an AltiSurf A520 machine equipped with a CL2 confocal sensor with a measuring range of $0 \div 400$ μm . The area of the scanned surface was $4 \text{ mm} \times 4 \text{ mm}$, the drilling in the X axis was $6 \mu\text{m}$, sampling in the Y axis – $0.6 \mu\text{m}$ with a scanning speed of $120 \mu\text{m/s}$, the brightness of the LED was 100% of the lighting power and the ambient temperature – 21°C . A fractional trivalent experiment plan was selected. Input factors are described in tab. II.

TABLE II. Description of selected input factors used in the planning of the experiment

Factor name	Range
PO mapped surface	–
A cutting thresholds	1. $0.01 \div 99.99$ 2. $0.05 \div 99.95$ 3. $0.10 \div 99.90$
B leveling	1. LS plane (by rotation) 2. LS plane (by subtraction) 3. Plane defined by three points (10 points)
C delete shape	1. 2nd order polynomial 2. 3rd order polynomial 3. 4th order polynomial
D filtering	1. Gaussian filter (cutoff 0.8 mm) 2. Coarse Gaussian filter (cutoff 0.8 mm) 3. Spline filter (cutoff 0.8 mm)

Variability of input factors specified in the plan is representative of all SGP testing equipment available on the market and compliant with [5]. According to the experiment plan, 27 experiment systems were analyzed and their results were developed in the AltiMap PREMIUM 6.2 program.

Processing the results

The analysis of research results was started by determining the significance of the impact of selected input factors on the value of the Sq parameter [7]. To better illustrate the changes that follow the subsequent stages of digital processing of the recorded point cloud, the coefficient of variation of the surface state KSx was determined:

$$KSx = \frac{Sx_{p0}}{Sx_x} \quad (2)$$

where: Sx_{p0} – value of the SGP parameter of the mapped surface, Sx_x – value of the SGP parameter of the surface after performing the specified digital processing operation.

Fig. 1 presents Sq values for the mapped surface and for the determined threshold values. Analyzing the individual stages of digital processing of surface data, it can be concluded that after removing the threshold values, the Sq value decreased proportionally to the value of the cut out percentage. For case A1 (see tab. II), the value of Sq decreased by 0.04%, for case A2 – by 0.18%, and for case A3 – by 0.35% (fig. 1).

Value of Sq parameter increased significantly after applying leveling relative to the surface mapped for B3. The plane defined by three points (10 points) increased by 48% for systems 7–9 and 25–27. The leveling method has significant impact on the Sq parameter. In other cases, its values decreased by 0.58% on average (fig. 2).

Fig. 1. Summary of the value of the Sq parameter of the mapped surface and the determined threshold value for 27 experiment systems

Fig. 2. Summary of the Sq parameter value for the level surface for 27 experiment systems

Fig. 3. Summary of the Sq parameter value of the surface with the shape removed and filtered for 27 experiment systems

Fig. 4. List of isometric images of milled samples: a) reproduced surface; b) cutting out threshold values; c) leveled surface; d), e) removing the shape; f) surface filtration

After removing the shape and filtering, the values of Sq parameter decreased by 20% on average. In two cases, for systems 3 and 8, the parameter values did not change. Fig. 4 shows system 1, visualizing the various stages of surface filtration.

Reduced values of the Sq parameter, determined by filtration from the mapped value, are smaller by approximately 22%, which is an important observation that affects the interpretation of measurement results.

Summary

The PN-EN ISO 25178-2: 2012 standards precisely define the relationships used to determine the values of individual SGP parameters, however, they do not clearly specify how to carry out the process of point cloud acquisition and what should be the methodology for processing measurement data by digital processing.

During the analysis, some trends were observed for the mean square surface deviation Sq . Considering the order of the data processing steps carried out, it can be seen that for 27 experimental systems the mapped surface was characterized by the largest parameter indications.

Significant impact of the digital processing of measurement data has been confirmed, resulting in a change in the Sq value – even by approximately 20% relative to the mapped value. Also, filtration has significant impact on reducing the value of Sq parameter by about 27%.

The consequence of the cause-effect relationships indicated in the paper is an ambiguous interpretation of the real quality of the processed surface. Based on the same measurement data, different conclusions can be drawn about the state of the surface depending on the method used for digital processing.

Based on the determined coefficient of variation, it was found out by how much the Sq parameter is reduced as a result of using the selected method of measuring signal processing.

It was confirmed that changes in the Sq parameter are the result of choosing a specific method of digital measurement data processing, and a problem was found related to the significant impact of the operator (metrologist) on the final results of the measurement procedure. The lack of harmonized standards regarding the point cloud acquisition procedure and the method of digital processing of measurement data gives the metrologist the opportunity to reduce the Sq parameter to the value given in the technological specification, which creates problems with achieving reproducibility of measurement results and should not occur in industrial practice. It is possible that the lack of repeatability of the measurement procedure will lead to complaints about production batches, which in fact comply with the customer's specification.

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