IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

The Effect of Spikes Occurrence on Surface Texture Parameter Assessments

To cite this article: P Podulka 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **473** 012039

The Effect of Spikes Occurrence on Surface Texture Parameter Assessments

P Podulka[1]

[1]Rzeszow University of Technology, The Faculty of Mechanical Engineering and Aeronautics, 35-959 Rzeszów, al. Powstańców Warszawy 12, Poland

Abstract. In this paper the influence of measurement errors (spikes) on surface topography parameter valuation was taken into consideration. More than 30 plateau-honed cylinder liner surfaces were taken into account. They were measured by white light interferometer Talysurf CCI Lite. The effect of two types of spikes (upper-spikes and/or lower-spikes) on areal form removal and/or surface texture parameter (from ISO 25178 standard) calculation was taken into account. It was assumed that surface topography parameters were falsely estimated when spikes appeared. Moreover, selection of reference plane was also disturbed when measurement errors (spikes) occurred.

1. Introduction

Surface topography measurement and/or analysis of cylinder liners is carefully considered; internal combustion engines are widely used in many applications. Assessment of this type of cylindrical elements is of a great importance especially with its improvement to air pollution, reduction of fuel consumption and emission. Since they consume fuel and contribute to air pollution, reducing of emission has an immense importance in environmental protection domain.

Surface topography is established in the final stage of a machining process. Its analysis is especially pertinent in assessment of functional properties (material contact, lubricant retention, wear resistance) [1]; the process of surface measurement should be subjected to strict control. Plateau-honed cylinder liner surface is an example of surface texture which consist of smooth plateau with valley. This type of surface is also characterized by highly acceptable sliding properties and lubricant maintains. Two-process surfaces have a decisive advantage over one-process surfaces [2].

Usually the surface topography parameters are calculated in relation to the reference plane [3] which is established with errors of form, waviness due to imperfections in manufacturing process. Surface topography areal form removal was often proposed by the cylinder fitting methods [4], polynomials [5], filtering methods [6-8], spline filters [9], wavelets [10] and other algorithms and/or procedures [11]. Many works were proposed for areal form removal [12, 13], some errors of two-process surface assessments with deep and wide valleys analysis were presented in [14-16].

The errors in surface topography analysis can be classified in measurement errors, the measured object errors [17], software and measuring method errors [18]. Moreover, there are some errors in measuring uncertainty, divided into: typical for measuring approaches, digitization process errors, errors obtained while data processing and/or other errors [19]. Sharp edges, inclusions, defects and other peculiarities of the surface can cause outliers and dropouts of data points in the topographical images measured with optical methods, more than with stylus technique [20].

There were many papers considering surface topography analysis of two-process surfaces [21]. However, the influence of measurement errors (spikes as an example) were not fully recognized when surface topography parameters were calculated. Moreover, the influence of individual peaks were not widely taken into account with filter appliances.

2. Materials and methods

In this paper plateau-honed cylinder liners with oil pockets created by the burnishing techniques were taken account. The average values of diameter and depth of oil pockets were around 0.25 mm and 7 µm correspondingly. They were measured by white light interferometer Talysurf CCI Lite; height resolution 0.01 nm; the maximum size of analysed surfaces was 3.35 x 3.35 mm; the spacing was 3.27 µm. More than 20 surfaces were analysed but only few of them were showed in details. Textures from cylindrical elements were carefully analysed.

For extraction of surface topography features and/or parameters the following types of pre-processing techniques were applied: polynomials of 2nd (P_2) and/or 4th (P_4) degrees, digital filtering: Gaussian regression filter (F_{GR}) and robust Gaussian regression filter (F_{RGR}). For spikes removal the thresholding method (proposed by the author of this article in previous researches) was recommended.

The effect of spikes occurrence on the following parameters (from ISO 25178 standard) was taken into consideration: root mean square height *Sq*, skewness *Ssk*, kurtosis *Sku*, maximum surface peak height *Sp*, maximum valley depth *Sv*, maximum height *Sz*, arithmetic mean height *Sa*; *Sk* group parameters: reduced summit height *Spk*, reduced valley depth *Svk*, core roughness depth *Sk*, upper bearing area *Sr1* and lower bearing area *Sr2*.

3. Results and discussions

Two-types of spikes were taken into consideration; measurement errors (individual peaks) were classified into: upper-spikes (a, b) and lower-spikes (c, d) – examples were presented with profile exploration in figure 1. When F_{GR} was applied it was assumed that plateau-parts of profiles were distorted when valleys and/or upper-spikes were near-distributed (it was indicated by the arrows in figure 2). Application of F_{RGR} caused the minimization of reference line distortion in accordance to the non-robust filtering method.

In figure 3-a examples of isometric view of white-light-method measured surface containing lower-spikes was presented. From the analysis of isometric view of studied details it was assumed that only small differences were obtained when spikes were removed after P_2 or P_4 appliance. However, when lower-spikes were removed before pre-processing, the values of height parameters decreased: *Sp*, *Sz*, *Sk*, *Spk*. It was also found that the influence of spikes occurrence increased when the degree of polynomial also increased; the highest degree was applied the highest variance of height parameters (between surfaces after pre-processing and before/after spikes removal) was observed.

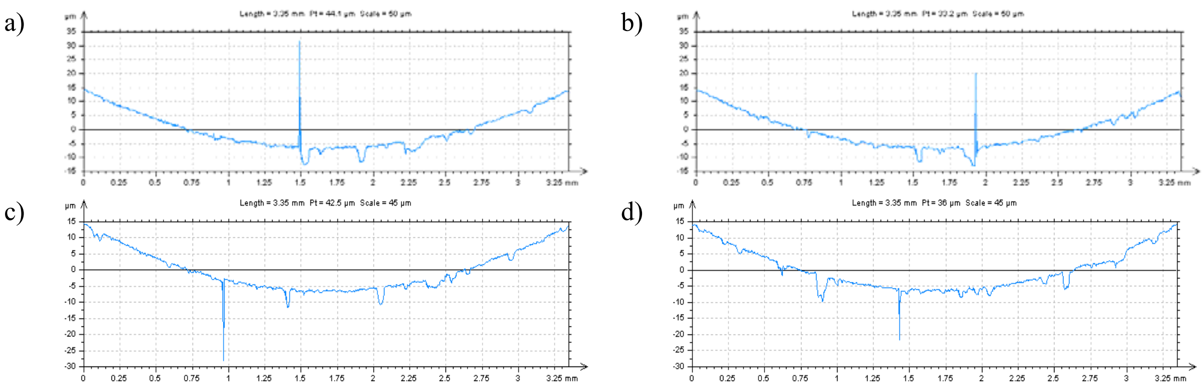


Figure 1. Examples of profiles extracted from surface measured by optical equipment, containing: upper- (a, b) and lower- spikes (c, d)

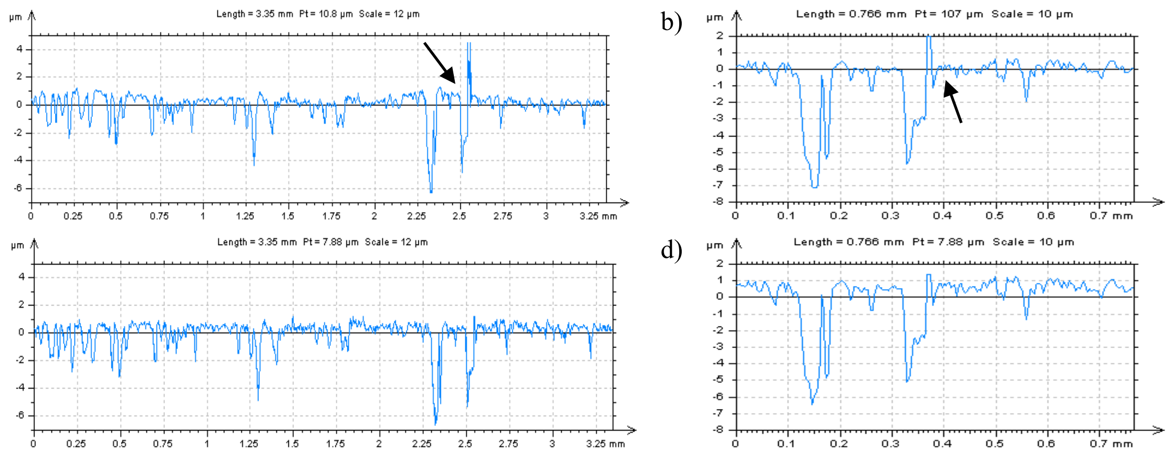
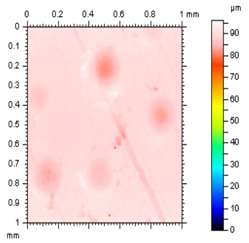
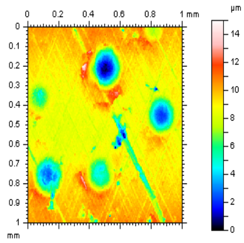


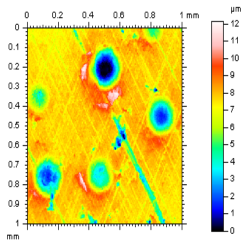
Figure 2. Profiles of surface after pre-processing by F_{GR} (a, b) and F_{RGR} (c, d) before (a, c) and after (b, d) upper-spikes removal; F_{COV} = 0.8 mm

a) 

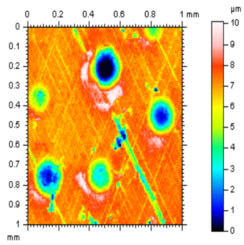
Sq = 1.77 µm, Ssk = -3.7, Sku = 97.2, Sp = 6.32 µm, Sv = 89.8 µm, Sz = 96.1 µm, Sa = 1.17 µm, Sk = 2.6 µm, Spk = 0.937 µm, Svk = 5.46 µm.

b) 

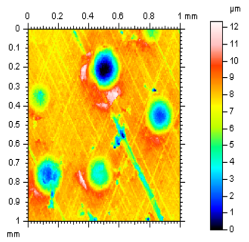
Sq = 1.72 µm, Ssk = -1.71, Sku = 6.8, Sp = 6.32 µm, Sv = 8.68 µm, Sz = 15.0 µm, Sa = 1.17 µm, Sk = 2.64 µm, Spk = 0.85 µm, Svk = 4.47 µm.

c) 

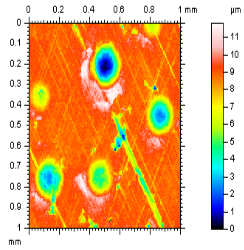
Sq = 1.57 µm, Ssk = -1.92, Sku = 7.74, Sp = 4.86 µm, Sv = 7.28 µm, Sz = 12.1 µm, Sa = 1.02 µm, Sk = 1.42 µm, Spk = 1.26 µm, Svk = 4.26 µm.

d) 

Sq = 1.56 µm, Ssk = -2.00, Sku = 7.56, Sp = 3.35 µm, Sv = 6.76 µm, Sz = 10.1 µm, Sa = 1.03 µm, Sk = 1.40 µm, Spk = 1.14 µm, Svk = 4.35 µm.

e) 

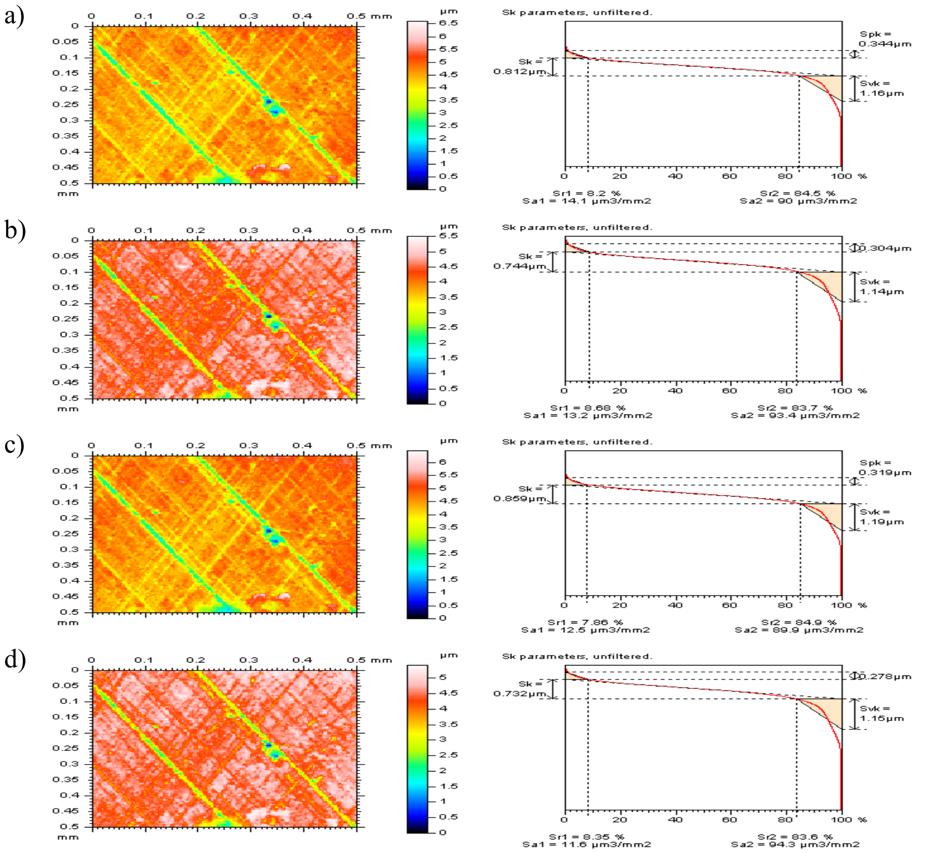
Sq = 1.57 µm, Ssk = -1.92, Sku = 7.84, Sp = 4.68 µm, Sv = 7.66 µm, Sz = 12.3 µm, Sa = 1.02 µm, Sk = 1.52 µm, Spk = 1.25 µm, Svk = 4.26 µm.

f) 

Sq = 1.59 µm, Ssk = -2.10, Sku = 8.13, Sp = 3.39 µm, Sv = 8.42 µm, Sz = 11.8 µm, Sa = 1.04 µm, Sk = 1.22 µm, Spk = 1.15 µm, Svk = 4.36 µm.

Figure 3. Isometric views of measured surface (a) and surface of lower-spikes removed (b) before (c, e) and after (d, f) pre-processing by: P_2 (c, d) and P_4 (e, f)

In figure 4 extracted free-of-dimples details with selected (likewise *Sk*) parameters were presented. The value of *Sq* parameter was minimized when pre-processing techniques were applied after spikes removal. Moreover, the value of *Sp* parameter decreased when spikes were removed before polynomial appliance. The value of *Sv* and *Svk* parameters did not changed or it was negligible. The maximum height of the surface was minimized with spikes removal before pre-processing techniques appliance; the minimum value of *Spk* parameter was received when P_4 was applied. When spikes were located near valleys/scratches, the reference line (plane) was non-accurate selected. Moreover, the spikes presence cause the increase of valley distortion when surface was pre-processed. For surface topography parameter calculation it is suggested to select the reference according to the *Sk* parameter value minimization.



a) Sq = 0.504 µm, Ssk = -1.86, Sku = 9.06, Sp = 2.17 µm, Sv = 4.43 µm, Sz = 6.60 µm, Sa =0.338 µm.

b) Sq = 0.490 µm, Ssk = -2.07, Sku = 9.65, Sp = 1.07 µm, Sv = 4.44 µm, Sz = 5.51 µm, Sa = 0.326 µm.

c) Sq = 0.515 µm, Ssk = -1.85, Sku = 8.67, Sp = 2.04 µm, Sv = 4.42 µm, Sz = 6.46 µm, Sa = 0.350 µm.

d) Sq = 0.486 µm, Ssk = -2.13, Sku = 9,79, Sp = 1.0 µm, Sv = 4.42 µm, Sz = 5.42 µm, Sa = 0.323 µm.

Figure 4. Details (and their material ratio curves with selected parameters respectively) extracted from surface with upper-spikes removed before (a, c) and after (b, d) pre-processing by P_2 (a, b) or P_4 (c, d)

4. Conclusions

The following conclusions and/or remarks were noticed:

1. Surface topography measurement by white light interferometry is fast but more sensitive to extraneous effects contrary to stylus methods. One of the measurement errors are spikes (upper-spikes and/or lower-spikes).

2. When upper-spikes were detected, the values of parameters describing plateau-part of surface increased; usually *Sp*, *Sz* and *Spk* parameters were overestimated more than 100%. For lower-spikes occurrence errors in calculation of *Sv* and *Svk* parameters increased; describing of *Sk* family parameters is of a great importance, false estimation of this type of parameters can cause a classification of properly made parts as a lacks and its rejection.

3. When form was removed by application of F_{GR} it was assumed that plateau-parts of profiles were distorted when valleys and/or upper-spikes were nigh-situated. Application of F_{RGR} caused the minimization of reference line distortion in accordance to the non-robust filtering method.

4. For procedure with lower-spikes removal before pre-processing, the values of height parameters (*Sp*, *Sz*, *Sk*, *Spk*) decreased. It was also found that the influence of spikes occurrence increased when the degree of polynomial increased; the highest degree was applied the highest variance of height parameters (between surfaces after pre-processing and before/after spikes removal) was noticed.

5. The maximum height of the surface (*Sz*) was minimized with spikes removal before pre-processing techniques appliance; the minimum value of *Spk* parameter was received when P_4 was applied. It is recommended to calculate the surface topography parameters of two-process surface with spikes removal before form elimination; areal form removal before spikes detection can cause the increase of errors in surface texture specification. Therefor for selection of reference plane the 4th degree of polynomial with spikes removal by thresholding method is suggested.

References

[1] Pawlus P 1994 *Wear* **176 (2)** 247-54.
[2] Jeng Y R 1996 *Tribol. Transact.* **39(2)** 354-61.
[3] Raja J, Muralikrishnan B and Fu S 2002 *Precis. Eng.* **26(2)** 222-35.
[4] Forbes A B 1989 Least squares best fit geometricelements. *NLP report DITC* **40(89)**, Teddington, UK.
[5] Podulka P, Dobrzański P, Pawlus P and Lenart A 2014 *Metrol. Measur. Syst.* **21(2)** 247–56.
[6] Brinkman S, Bodschwinna H 2000 Advanced Gaussian Filters. [in] *Advanced Techniques for Assessment Surface Topography*, Elsevier.
[7] Podulka P 2016 *Adv. Sci. Tech. Res. J.* **10(30)** 164–75.
[8] Janecki D 2011 *Precis. Eng.* **35(4)** 602–6.
[9] Muralikrishnan B and Raja J 2009 *Computational surface and roundness metrology*, Springer.
[10] De Chiffre L, Lonardo P, Trumpold H, Lucca D A, Goch G, Brown C A, Raja J and Hansen H N 2000 *Ann. Manuf. Technol.* **49(2)** 635–642, 644–652.
[11] Mainsah E, Greenwood J A and Chetwynd D G 2001 *Metrology and Properties of Engineering Surfaces*, Springer.
[12] Yuan Y-B, Qiang X-F, Song J-F and Vorburger TV 2000 *Prec. Eng.* **24(1)** 62–9.
[13] Stout K J, Sullivan P J, Dong W P, Mainsah E, Luo N, Mathia T and Zahouani H 1993 *Publication EUR 15178 EN Commission of the European Communities*.
[14] Podulka P 2018 Problem of selection of reference plane with deep and wide valleys analysis. *Journal of Physics: Conference Series* **1065(7)** 072017.
[15] Godi A, Grønbæk J and De Chiffre L 2017 *CIRP J. Manuf. Sci. Tech.* **16** 64-71.
[16] Podulka P 2018 Edge-area form removal of two-process surfaces with application of valley excluding method. Computational Metods in Engineering Science 2018 (CMES 2018), *E3S Web of Conferences.* (to be published)
[17] Stout K J (ed) 1994 Three-dimensional surface topography – measurement, interpretation and application. *Penton Press*, London.
[18] Thomas T R 1999 Rough Surfaces. Second Edition. *Imperial College Press*, London.
[19] Magdziak M 2017 *Aircraft Eng. Aerosp. Tech.* **89(6)** 953-9.
[20] Podulka P, Pawlus P, Dobrzański P and Lenart A 2014 Spikes removal in surface measurement *Journal of Physics: Conference Series* **483(1)** 012025.
[21] Podulka P 2018 Proposal of edge-area form removal of cylindrical surfaces containing wide dimples by application of various robust processing techniques. *Journal of Physics: Conference Series* **1065(7)** 072018.