ISSN 2078-7405 Cutting & Tools in Technological System, 2026, Edition 104

UDC 621.9.048 **doi: 10.20998/2078-7405.2026.104.13**

ANALYSIS OF FUNCTION-DEFINING 3D SURFACE PARAMETERS IN DIAMOND BURNISHING

Viktoria **Ferencsik** [0000-0002-8673-1095]

University of Miskolc, 3515 Miskolc-Egyetemváros, Hungary
ferencsik.viktoria@uni-miskolc.hu

Received: 22 April 2026 / Revised: 26 April 2026 / Accepted: 28 April 2026 / Published: 15 May 2026

Abstract. *The tribological effects of diamond burnishing are investigated on EN AW-2011 aluminium alloy cylindrical surfaces. In engineering practice, the tribological behaviour of machined parts is often characterized using functional surface roughness parameters such as the* S_k *(core roughness depth),* S_{pk} *(reduced peak height), and* S_{vk} *(reduced valley depth) 3D roughness parameters. In the present study, the influence of various burnishing parameter settings is evaluated comprehensively through both their quantitative roughness values and the corresponding Abbott-Firestone material ratio curves. This combined approach enables a deeper understanding of how the burnishing process modifies the surface topography and, consequently, the tribological performance of the material under operational conditions.*

Keywords: *diamond burnishing; surface roughness; functional parameters, Abbott-Firestone.*

1. Introduction

Surface burnishing is a cold plastic finishing technique in which a hard (typically PCD) tool plastically deforms the surface layer of a workpiece to improve its overall surface integrity. During the process, the applied force, in combination with the selected burnishing parameters, induces material flow in the near-surface region, resulting in enhanced smoothness and improved functional properties [1–3]. In contrast to conventional abrasive methods such as grinding or honing, burnishing does not involve material removal; instead, it generates beneficial compressive residual stresses, increases surface hardness, and significantly reduces surface roughness. The appropriate selection of burnishing parameters is therefore essential to achieve optimal performance characteristics in the final component [4].

Due to various disturbances inherent in machining processes, the resulting surface profile often contains irregular features whose geometry may deviate significantly from idealized forms. Consequently, surfaces produced by manufacturing operations typically exhibit highly complex topographies and textures. In such cases, three-dimensional surface roughness analysis provides a more comprehensive characterization of surface features compared to conventional two-dimensional evaluation methods [5]. Therefore, Sztankovics [6], in order to ensure a comprehensive evaluation of surface topography, selected six S-parameters for tangential turning analysis. A general parameter was chosen to describe the overall surface texture. In addition, three parameters derived from the Abbott-Firestone curve were included to characterize the material ratio curve and to provide insight into the load-bearing properties of the surface. Furthermore, two functional parameters were also considered in the surface description, as they are critical for evaluating surface functionality in machining applications.

Nagy [7] examined the functional parameters in the case of face milling, while Kebede et al. [1] also examined them in the case of surface burnishing because slide burnishing plays a significant role in improving surface quality, but there is a noticeable lack of studies addressing the efficiency of the process.

The current paper aims to contribute to a deeper understanding of burnishing process and its role in enhancing the functional performance of critical mechanical components with particular emphasis on the tribological significance of functional surface parameters governing friction, wear, and lubrication behaviour on low alloyed aluminium workpieces.

2. Experimental conditions

For the investigation, burnishing experiments were carried out on an E400 universal lathe (the surface of the workpiece was pre-machined by finishing turning set at f_1 = 0.2 than f_2 = 0.15 mm/rev) using PCD (polycrystalline diamond) tool with 3.5 mm radius (r). During cylindrical surface burnishing, the workpiece rotates at a defined speed (ω_w) while a deforming tool passes over its surface under burnishing force (F_b) with defined feed rate (f), causing elastic-plastic deformation in the near-surface layer [8], as shown in Figure 1.

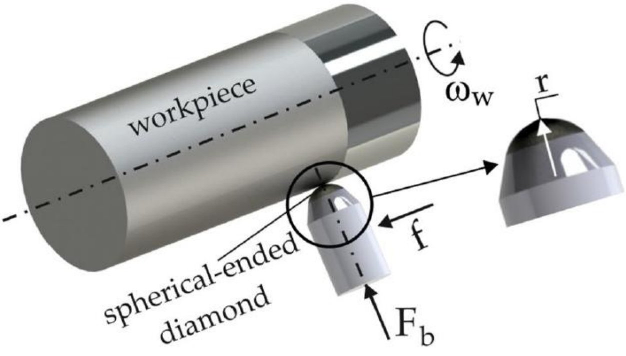


Figure 1 – Scheme of burnishing process on external cylindrical surface [8]

The application of this finishing process aims to improve surface quality and prolong component lifetime by inducing compressive residual stresses and increasing the hardness of the near-surface layer [9, 10].

Table 1 summarizes the adjusted burnishing parameters (F – burnishing force, f – feed, v – burnishing speed, i – number of passes) derived from preliminary experimental work, with due consideration given to the mechanical properties of the workpiece material (EN AW-2011) subjected to burnishing.

Table 1 – Numerical value of the analysed burnishing parameters

No	**F [N]**	**f [mm/rev]**	**v [m/min]**	**i [-]**
1	15	0.05	50.54	2
2	25	0.05	50.54	2
3	35	0.05	50.54	2
4	25	0.01	50.54	2
5	25	0.1	50.54	2
6	25	0.05	35.71	2
7	25	0.05	71.43	2
8	25	0.05	50.54	1
9	25	0.05	50.54	3

3. Evaluation of 3D surface roughness

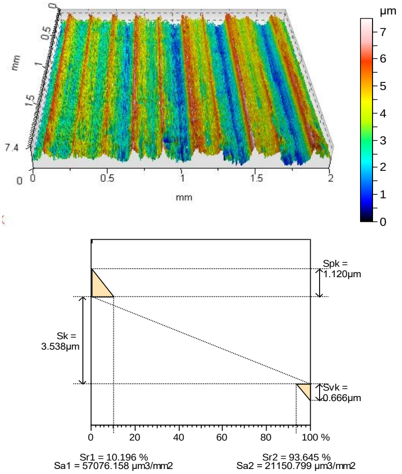
The 3D surface roughness of turned and burnished surfaces was measured in three 2 × 2 mm regions, separated by a 120° rotational angle. Measurements were performed using an Altisurf 520 surface profiler with a CL2 confocal chromatic sensor and MG140 magnification. Data evaluation was carried out using Altimap Premium software.

To evaluate the surface topography, three S-parameters were selected for the analysis: S_k – core roughness depth, S_{vk} – reduced valley depth, S_{pk} – reduced peak height. These parameters, derived from the Abbott-Firestone curve, are used to characterize the material ratio curve and to determine the load-bearing properties of the surface [9]. Their selection is further justified by the fact that burnishing improves the bearing area ratio by effectively flattening surface asperity peaks, thereby modifying the functional surface profile. Using this approach, the aim of the study was to define a practical and effective evaluation range that provides reliable S-parameter values.

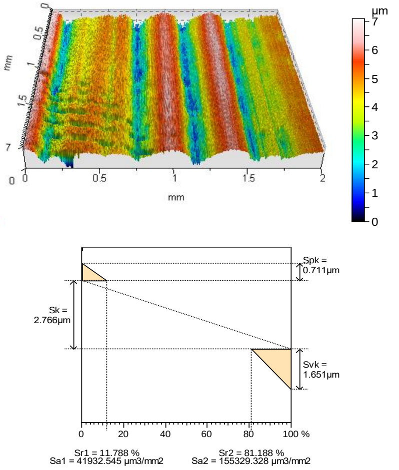
4. Results

The surface topographies obtained from the measurements were analysed together with their corresponding Abbott-Firestone material ratio curves in order to evaluate the functional characteristics of the machined surfaces. Representative examples of the measured 3D surface topographies and material ratio curves are presented in the paper for specimens No. 1 and No. 9 to illustrate the effects of the applied processing conditions.

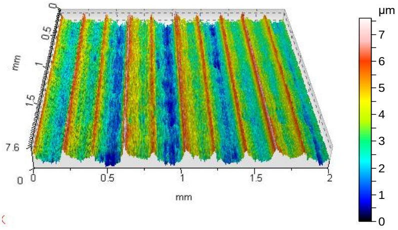
The evaluated 3D surface topographies reveal a clear modification of the surface structure induced by the burnishing process. Compared to the turned surfaces, the burnished specimens exhibit a more uniform height distribution, reduced peak prominence, and smoother surface features aligned with the processing direction. These changes indicate effective plastic deformation of surface asperities, consistent with the observed improvements in functional roughness characteristics and the corresponding behaviour of the Abbott-Firestone material ratio curve.

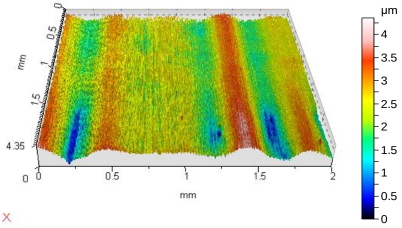


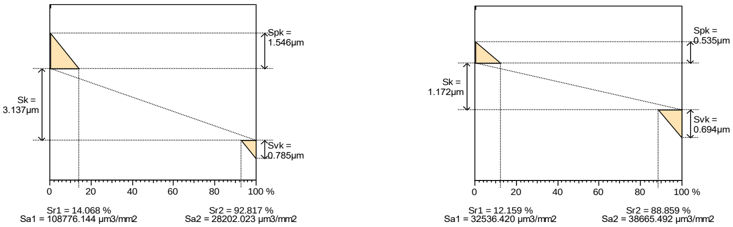
No. 1.1 Turned



No. 1.1. Burnished







No. 9.1 Turned   No. 9.1. Burnished

Figure 2 – Measured 3D surface morphology illustrating the effect of burnishing

Table 2 presents the averaged values of the measured roughness parameters and includes dimensionless ratios introduced to facilitate a clearer interpretation of the observed changes. The calculations were performed in accordance with the methodology proposed by El-Taweel and El-Axir [10].

$$\Delta\rho_{S_x}\% = \left(\frac{S_{x_{\text{before}}} - S_{x_{\text{after}}}}{S_{x_{\text{before}}}}\right) \cdot 100\%, \qquad (1)$$

where:

$S_{x\ \text{before}}$	Surface roughness parameter measured after turning,
$S_{x\ \text{after}}$	Surface roughness parameter measured after burnishing,
$\Delta\rho S_x\%$	Percentage value of the calculated ratio.

Table 1 – The results of S_k, S_{vk} and S_{pk} with the calculated ratios of the experiment

No.	**S_k [µm]**		**$\Delta\rho_{S_k}$ [%]**
	before	**after**	
1	3.232	2.251	30.359
2	2.982	0.878	70.557
3	0.809	0.904	-11.743
4	0.839	0.917	-9.297
5	0.845	1.063	-25.799
6	3.285	0.933	71.598
7	3.042	1.063	65.056
8	3.643	1.341	63.189
9	3.351	1.038	69.024

No.	**S_{vk} [µm]**		**$\Delta\rho_{S_{vk}}$ [%]**
	before	**after**	
1	0.601	1.141	-89.850
2	0.733	0.509	30.559
3	0.674	0.371	44.955
4	0.422	0.375	11.137
5	0.413	0.466	-12.833

6	0.711	0.344	51.617
7	0.593	0.394	33.558
8	0.654	0.700	-7.034
9	0.829	0.528	36.309

No.	S_{pk} **[µm]**		$\Delta\rho_{S_{pk}}$ **[%]**
	before	**after**	
1	1.311	0.479	63.463
2	1.255	0.297	76.335
3	0.402	0.419	-4.229
4	0.325	0.292	10.154
5	0.351	0.770	-119.373
6	1.761	0.321	81.771
7	1.603	0.436	72.801
8	1.153	0.424	63.226
9	1.443	0.483	66.528

The evaluated improvement ratios indicate that the surface labelled No. 6 was produced under the most favourable set of process parameters. The optimal surface roughness characteristics were achieved with a burnishing force of F = 25 N, a feed rate of f = 0.05 mm/rev, burnishing speed of v = 35.71 m/min, and two burnishing passes (i = 2). Furthermore, the influence of the investigated burnishing parameters, presented along the horizontal axis, on the corresponding improvement ratios shown on the vertical axis is illustrated in Diagrams 1-4.

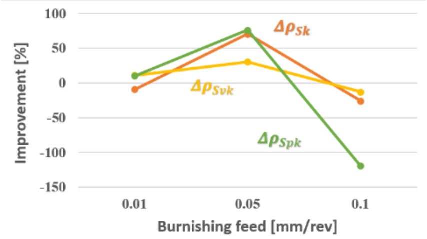


Diagram 1 – Effect of feed rate

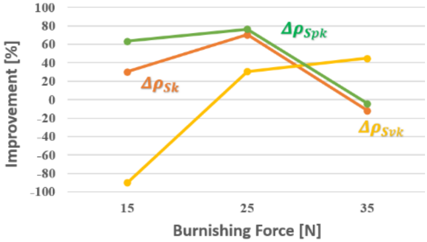


Diagram 2 – Effect of force

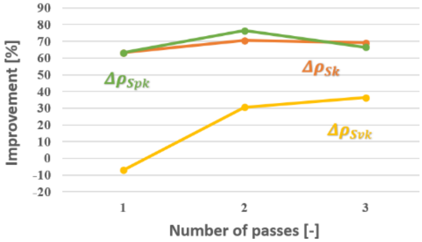


Diagram 3 – Effect of number of passes

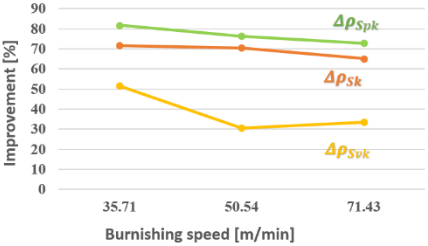


Diagram 4 – Effect of speed

The presented diagrams provide a comparative overview of the influence of the investigated burnishing parameters on surface roughness improvement ratios. In general, higher improvement values correspond to a more pronounced enhancement of surface condition as a result of the burnishing process. The observed trends clearly demonstrate that the applied technological parameters have a significant impact on the achievable surface quality, thereby underlining the importance of parameter optimization in burnishing operations.

5. Conclusions

The paper presents an experimental investigation of slide burnishing applied to low-alloyed aluminium workpieces, focusing on the effects of burnishing force, feed rate, burnishing speed and number of passes on selected functional 3D surface roughness parameters. The surface integrity was evaluated using the S_k (core roughness depth), S_{pk} (reduced peak height), and S_{vk} (reduced valley depth) parameters, which are closely related to load-bearing capacity, initial wear behaviour, and lubricant retention.

Based on the measured values before and after burnishing, the calculated improvement ratios, and their graphical representation, the following main conclusions can be drawn:

- The most favourable overall modification of the functional surface characteristics was observed for the specimen marked No. 6. In this case, S_k decreased from 3.285 µm to 0.933 µm (71.6% improvement), S_{pk} was reduced from 1.761 µm to 0.321 µm (81.8% improvement), while S_{vk} decreased from 0.711 µm to 0.344 µm (51.6% improvement). These results indicate a significantly smoother surface with reduced asperity peaks and a stabilized core structure as a result of the burnishing process.
- The numerical results clearly show that unfavourable parameter combinations can lead to a deterioration of functional roughness properties. This phenomenon is evident for example in specimen No. 5, where increases in S_k (+25.8%), S_{pk} (+119.4%), and S_{vk} (+12.8%) were observed, confirming that higher feed rate and burnishing speed settings adversely affect the surface modification efficiency.
- The tendencies observed in the improvement ratio diagrams suggest that the burnishing parameters should not be considered independently but rather in a combined manner; an increased burnishing force is particularly effective at moderate feed rates, where longer tool-surface contact time enhances the redistribution of material from peaks toward valleys, leading to reduced S_{pk} values and a more stable S_k core structure. Overall, the results indicate that optimal burnishing performance is obtained through a well-balanced combination of process parameters, in which a moderate feed rate, adequately

high burnishing forces, and modest speeds act synergistically to improve the functional surface roughness parameters.

- The simultaneous reduction of S_{pk} and S_k, together with a controlled modification of S_{vk}, indicates that slide burnishing leads to a more favourable functional surface topography. These changes result in improved load-bearing capacity, reduced initial wear tendency, and a more balanced lubricant retention behaviour. Consequently, the optimized burnishing conditions enhance the overall tribological performance of the machined surface.

Future research will focus on the investigation of additional functional and spatial 3D surface parameters, as well as on further optimization of burnishing parameters, in order to gain a more comprehensive understanding of the surface transformation mechanisms governing tribological performance.

References: **1.** *Kebede, F. T., Felhő, C, Sztankovics, I.,* Improving surface roughness of 42CrMo4 low alloy steel shafts by applying varying feed in the multi-pass slide burnishing process. Applied Sciences. 2025. vol. 15. pp. 1–22 **2.** *Smolnicki, S., Varga, G.,* Analysis of surface roughness of diamond-burnished surfaces using Kraljic Matrices and experimental design. Applied Sciences-Basel. 2025. vol. 15. pp. 1–24. **3.** *Kovács, Z. F., Viharos, Z. J., Kodácsy, J.,* Improvements of surface tribological properties by magnetic assisted ball burnishing. Surface & Coatings Technology. 2022. vol. 437. pp. 1–12 **4.** *Ferencsik, V., Varga, G.,* The influence of diamond burnishing process parameters on surface roughness of low-alloyed aluminium workpieces. Machines. 2022. vol. 10. pp. 1–11 **5.** *Grzesik, W., Zak, K.,* Modification of surface finish produced by hard turning using superfinishing and burnishing operations. Journal of Materials Processing Technology. 2012. vol. 212. pp. 315–322. **6.** *Sztankovics, I.,* Optimization of measurement area selection for accurate 3D surface topography characterization in high-feed tangential turning of 42CrMo4 alloy steel. Metrology. 2025. vol. 5. pp. 1–22. **7.** *Nagy, A.,* Functional roughness parameter characterization of a plane surface face-milled with an octagonal insert. Fiatalok a Tudományért 2024. 2024. (in Hungarian) pp. 51–56. **8.** *Maximov, J., Duncheva, G.,* Effect of diamond burnishing process on surface integrity, fatigue, wear, and corrosion of metal components – review and perspectives. The International Journal of Advanced Manufacturing Technology. 2025. vol. 139. pp. 4233–4267. **9.** ISO 22081:2021, Geometrical product specifications (GPS) — Geometrical tolerancing — General geometrical specifications and general size specifications, (2021), https://www.iso.org/standard/72514.html (Viewed: 14/09/24) **10.** *El-Taweel, T.A., El-Axir M.H.,* Analysis and optimization of the ball burnishing process through the Taguchi technique. International Journal of Advanced Manufacturing Technologies. 2009. vol. 41. pp. 301–310.

Вікторія Ференчик, Мішкольц, Угорщина

АНАЛІЗ ФУНКЦІЙНО-ВИЗНАЧЕНИХ ПАРАМЕТРІВ 3D-ПОВЕРХНІ, ПРИ АЛМАЗНОМУ ПОЛІРУВАННІ

Анотація. *Трибологічні ефекти алмазного вигладжування досліджуються на циліндричних поверхнях алюмінієвого сплаву EN AW2011. В інженерній практиці трибологічну поведінку оброблених деталей часто характеризують за допомогою параметрів шорсткості функціональної поверхні, таких як S_k (глибина шорсткості ядра), S_{pk} (зменшена пікова висота) та S_{vk} (зменшена глибина западини) 3D шорсткості. У цьому дослідженні комплексно оцінюється вплив різних параметрів полірування через їхні кількісні значення шорсткості та відповідні криві* *співвідношення матеріалів Еббопта-Файрстоуна. Такий комбінований підхід дозволяє глибше зрозуміти, як процес полірування змінює топографію поверхні і, відповідно, трибологічні характеристики матеріалу в експлуатаційних умовах. Виходячи з виміряних значень до і після полірування, розрахованих коефіцієнтів покращення та їх графічного представлення, можна зробити деякі основні висновки. Найбільш сприятлива загальна модифікація функціональних характеристик поверхні була зафіксована для зразка, позначеного No6. У цьому випадку S_k зменшився з 3,285 мкм до 0,933 мкм (покращення на 71,6%), S_{pk} зменшився з 1,761 мкм до 0,321 мкм (покращення на 81,8%), а S vk зменшився з 0,711 мкм до 0,344 мкм (покращення на 51,6%). Ці результати свідчать про значно гладкішу поверхню з зменшеними піками асперності та стабілізовану структуру ядра внаслідок процесу полірування. Чисельні результати чітко показують, що несприятливі комбінації параметрів можуть призводити до погіршення функціональних властивостей шорсткості. Це явище помітне, наприклад, у зразку No5, де спостерігалося збільшення S_k (+25,8%), S pk (+119,4%) та S_{vk} (+12,8%), що підтверджує, що вища швидкість подачі та швидкість полірування негативно впливають на ефективність модифікації поверхні. Тенденції, виявлені на діаграмах коефіцієнтів покращення, свідчать, що параметри полірування слід розглядати не окремо, а в комбінованому вигляді; збільшена сила полірування особливо ефективна при помірних швидкостях подачі, де є довший час контакту з поверхнею інструменту, покращує перерозподіл матеріалу від піків до западин, що призводить до зниження значень S_{pk} і більш стабільної структури ядра S k. Загалом результати свідчать, що оптимальна ефективність полірування досягається завдяки добре збалансованому поєднанню параметрів процесу, де помірна швидкість подачі, достатньо високі сили полірування та помірні швидкості взаємодіють синергічно для покращення функціональних параметрів шорсткості поверхні. Одночасне зменшення S_{pk} і S_k, разом із контрольованою модифікацією S_{vk}, свідчить про те, що полірування зразка призводить до більш сприятливого функціонального рельєфу поверхні. Ці зміни призводять до покращення несучої здатності, зниження початкової схильності до зношування та більш збалансованої поведінки утримання мастила. Відповідно, оптимізовані умови полірування покращують загальні трибологічні характеристики обробленої поверхні. Майбутні дослідження будуть зосереджені на вивченні додаткових функціональних і просторових 3D-параметрів поверхні, а також на подальшій оптимізації параметрів полірування, щоб отримати більш повне розуміння механізмів трансформації поверхні, що регулюють трибологічну продуктивність.*

Ключові слова: *алмазне полірування; шорсткість поверхні; функціональні параметри Abbott-Firestone.*