UDK 621.923.7 **doi: 10.20998/2078-7405.2022.97.07**

V. Ferencsik, G. Varga, Miskolc, Hungary

THE EFFECT OF BURNISHING PROCESS ON SKEWNESS AND KURTOSIS OF THE SCALE LIMITED SURFACE

Abstract. *In this paper roughness examination and analysis on burnished low alloyed aluminium surfaces are reported, highlighting 2 parameters from the vertical deviations of the roughness profile from the mean line. From the input parameters of the burnishing process, the effect of burnishing force, feed rate, speed and number of passes are investigated. Measurements of the surface topography – before and after burnishing – are conducted on an Altisurf 520 3D measuring device. The generated and calculated values of the machined surface roughness are analysed in detail with the drawing of the conclusions as well.*
Keywords: *low-alloy aluminum; smoothing; surface roughness; parameters of the 3D topography of the surface.*

1. INTRODUCTION

The quality of the machined surface is crucial for mechanical parts as, it is an indicator of surface integrity, thus it has a direct impact on the properties and complete lifetime of the product [1]. For this reason, measuring and evaluating the surface roughness of machined parts is a widely used method in industry [2–4]. As a result of the ever-higher requirements, many measurement methods and techniques have been developed which are partly contained in standards [5, 6], and partly in the literature that provide new possibilities.

The cornerstone of the 3D evaluation technique was laid by Stout et al., when they interpreted 3D surface roughness and defined 3D metrics in their publication [7]. The scientific interest in surface topography is due to the fact that it enables a significantly more realistic analysis of the surface [8], so many researchers have dealt with investigation of this topic.

Dzionk et al. investigated and compared different 3D amplitude roughness parameters on burnished hardened C53 material shafts when the tool was Si_3N_4 ceramic ball [9]. In certain cases they managed to achieve 3.5 times better roughness values. Skoczylas et al. [10], beyond surface micro-hardness, examined S_a and S_z parameters and according to the results the values of these were effected by mostly the burnishing force. In contrast, Luo et al. [11] experienced that higher burnishing depth and speed cause higher improvement when non-ferrous materials (LY12 aluminium alloy and H62 brass) were burnished with PCD tool. In this paper, we study the effect of burnishing force (*F*), feed (*f*), speed (*v*), and number passes (*i*) on 2 kinds of 3D roughness parameters (S_{sk}, S_{ku}) investigating the correlation between these setting parameters on low alloyed aluminium workpieces.

2. IMPLEMENTATION OF BURNISHING PROCESS

Burnishing is one of the cold plastic forming procedures which utilizes the mechanics of mechanical deformation and it is suitable for machining external cylindrical surfaces. The process has many advantages: it reduces surface roughness, increases micro-hardness, while causes compressive residual stress, improves shape correctness and it is environmentally friendly because it does not require a high amount of coolant and lubricant [12–16].

The mechanism of burnishing is shown in Fig. 1., in which a rigid ball with certain parameters and defined force passes on the surface of the rotating workpiece while performing a rectilinear movement.

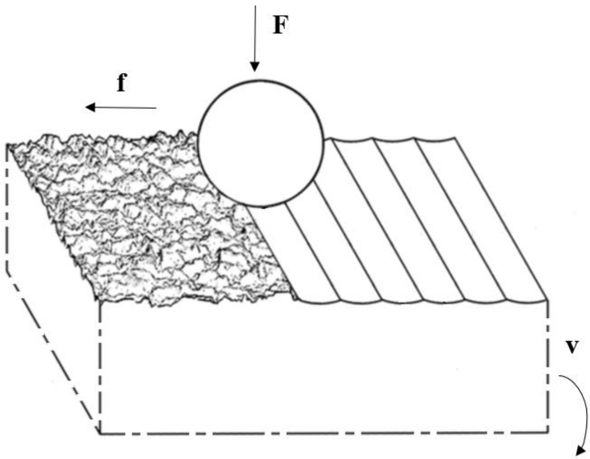

Figure 1 – Schematic illustration of burnishing [17]

In this study, the material of the examined cylindrical workpieces was EN AW-2011 grade low alloyed aluminium as extending the exact knowledge of machinability of non-ferrous materials is a major field in many industries (automotive, aeronautics, aerospace) due to their low density and good mechanical properties [18–20].

Before burnishing, finish turnings were carried out set at f_1 = 0.2 mm/rev, than f_2 = 0.15 mm/rev. Burnishing process was realized with the same machine (E400 universal lathe) using r = 3.5 mm radius PCD spherical tool. The kinematic viscosity of the manually dosed oil was ν = 70 mm^2/s.

Table 1. contains the adjusted burnishing parameters, which were determined based on preliminary experimental work.

Table 1 – Applied 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. MEASURING OF THE 3D SURFACE ROUGHNESS

Many methods and techniques are known for characterizing surfaces and measuring surface roughness. It is important and necessary to review the measurement practice, the setting and standardization requirements of the measurement conditions, especially in the case of 3D topographic measurement and evaluation [21].

In this experiment, measurements of 3 areas of 2x2 mm rotated by 120° were implemented with an Altisurf 520 3D surface topography measuring device before and after burnishing. CL2 confocal chromatic sensor was used, the cut-off was 0.8 mm and Gauss filter was applied.

Results were evaluated with Altimap Premium software, Fig. 2 shows a state during measuring process.

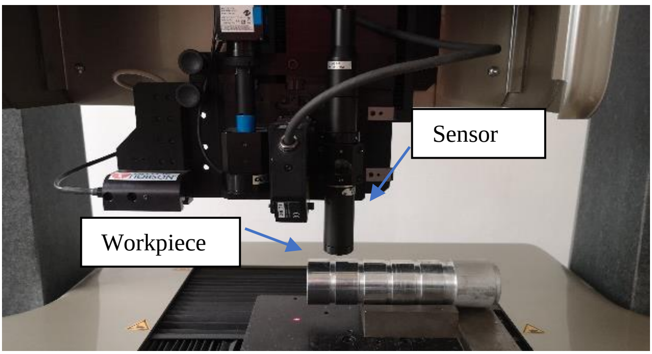

Figure 2 – Working area of the measuring device

The 3D roughness parameters can be classified into 6 groups, one of them is the amplitude parameters [22], Table 2 includes which 2 parameters from those were examined.

Table 2 – Examined 3D roughness parameters according to EN ISO 25178 [23]

Mark	Name	Definition	Formula
S_{sk}	Skewness of the scale limited surfaces	Represents the degree of bias of the roughness shape (asperity)	$\frac{1}{S_q{}^3}\left[\frac{1}{A}\iint_A Z^3(x,y)dxdy\right]$
S_{ku}	Kurtosis of the scale limited surface	The value of it is a measure of sharpness of the roughness profile	$\frac{1}{S_q{}^4}\left[\frac{1}{A}\iint_A Z^4(x,y)dxdy\right]$

4. RESULTS

Table 3–4 summarizes the averaged values of the measured roughness parameters and contains dimensionless ratios that were created to make more illustrative the changes.

For S_{sk} parameter the calculations were made according to El-Taweel and El-Axir [24]:

$$\Delta\rho_{S_{sk}}\% = \left(\frac{S_{sk_{before}} - S_{sk_{after}}}{S_{sk_{before}}}\right) \cdot 100\%, \quad (1)$$

where:

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

Table 3 – The results of S_{sk} with the calculated ratios of the experiment

No.	S_{sk} [µm]		$\Delta\rho_{S_{sk}}$ [%]
	before	after	
1	0.4033	-0.5941	247.31
2	0.3373	-0.4502	233.47
3	-0.5299	0.2204	-141.59
4	-0.1326	-0.1361	2.64
5	0.0988	0.5335	-439.98
6	0.5559	-0.0160	102.88
7	0.5461	0.0015	99.73
8	0.3335	-0.3031	190.88
9	0.2222	-0.0068	103.06

The smaller the value of S_{sk} become, the better the change, because in the case of a negative S_{sk}, it is a surface with good bearing properties and wear-resistant. In the case of a positive value of S_{sk}, there are sharp peaks on the surface, which result in very fast initial wear.

As S_{ku} expresses the dispersion range of the topography, and for Gaussian surfaces S_{ku} = 3 [25], therefore, the ratios express the deviation from this value, as the closer $\Delta_{S_{ku}}$ is to zero, the better its value due to burnishing. Measurement results of S_{ku} before and burnishing are shown in Table 4 as an illustration.

$$\Delta S_{ku} = 3 - S_{ku\_b/a} \tag{2}$$

Table 4 – The results of S_{ku} with the calculated ratios of the experiment

No.	S_{ku} [μm] before	ΔS_{ku_b} [μm]	S_{ku} [μm] after	ΔS_{ku_a} [μm]
1	2.5835	0.4165	3.0478	-0.0478
2	2.7854	0.2146	3.7455	-0.7455
3	6.4683	-3.4683	3.9387	-0.9387
4	3.3558	-0.3558	3.0667	-0.0667
5	3.7699	-0.7699	4.3709	-1.3709
6	2.7839	0.2161	3.2129	-0.2129
7	2.6563	0.3437	3.0571	-0.0571
8	2.6515	0.3485	3.4251	-0.4251
9	2.5508	0.4492	4.9857	-1.9857

The influences of investigated burnishing parameters (horizontal axis) on calculated ratios and deviations (vertical axis) are presented in diagrams (Diagram 1-4).

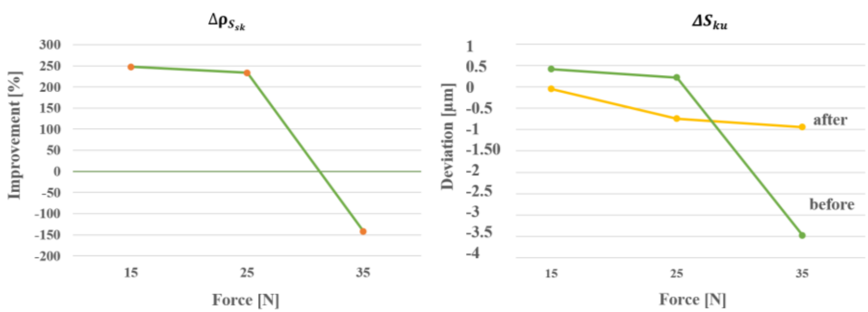

Diagram 1 – The effect of burnishing force on the analysed parameters

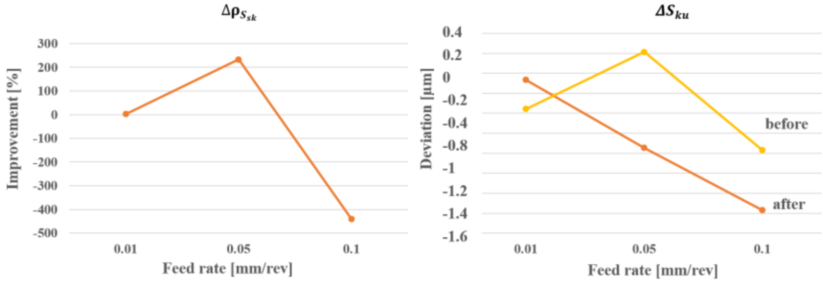

Diagram 2 – The impression of feed rate on the analysed parameters

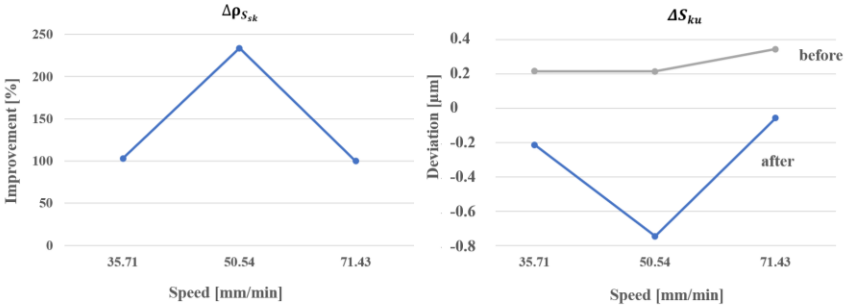

Diagram 3 – The impression of speed on the analysed parameters

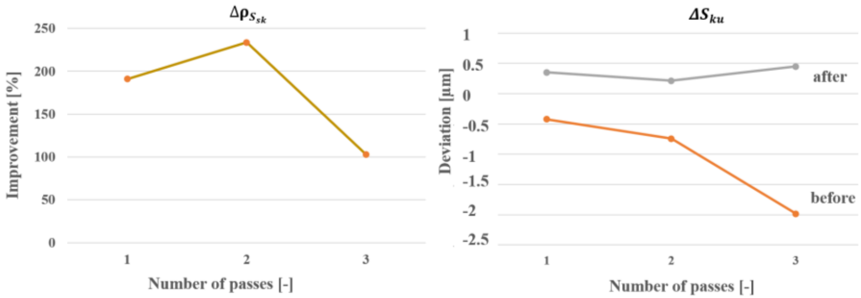

Diagram 4 – The impression of number of passes on the analysed parameters

The calculated results and the diagrams clearly show that the most advantageous parameter setting was in the case of marked 1 surface. So, applying F = 15 N burnishing force with f = 0.05 mm/rev feed rate, and 50.54 m/min speed with i = 2 number of passes produces the most preferred surface roughness values.

5. SUMMARY

This paper analysed the burnishing process on low alloyed aluminium cylindrical workpieces, where the considered parameters were burnishing force, feed rate, speed and number of passes. From the 3D amplitude roughness parameters the skewness and kurtosis of the scale limited surface were tested. According to the measured and calculated results, following conclusions can be made:

- The most approving changing in surface roughness was experienced in case of marked 1 surface and further results demonstrate that setting of F = 15 N force with f = 0.05 mm feed rate is the most beneficial.
- The numerical experiment results also obviously prove that the higher feed rate and speed adversely affect the change in surface roughness as, in case of 5 marked surface all 3D roughness parameters deteriorated to a great extent.
- Our future plans include investigating further 3D roughness parameters in order to better understand the process taking place during machining.

ACKNOWLEDGEMENTS

"Project no. NKFI-125117 has been implemented with the support provided from the National Research, Development and Innovation Fund of Hungary, financed under the K_17 funding scheme."

References: 1. *J. Kundrák, A. Nagy, A.P. Markopoulos, N.E. Karkalos*: Investigation of surface roughness on face milled parts with round insert in planes parallel to the feed at various cutting speeds, Rezanie I Instrumenty V Tekhnologicheskih Sistemah 91, (2019) 87-96. **2.** *G. N. Tóth, Á. Drégelyi-Kiss, B. Palásti-Kovács:* Analysis of the microgeometric parameters of cut surfaces, Pollack Periodica: an international journal for engineering and information sciences vol. 8 (2013). 55-66. **3.** *Á. Drégelyi-Kiss, Á. Czifra, B. Palásti-Kovács:* Comparison of capability calculations of surface roughness measurement in automotive industry, Proceedings of the ISMQC (2013) 1-8. **4.** *V. Molnár, I. Sztankovics:* Analysis of Roughness Parameters Determining Tribological Properties in Hard Turned Surfaces, Hungarian Journal Of Industry And Chemistry 49:2 (2021) 77-84. **5.** EN ISO 4287 Geometrical Product Specification (GPS) - Surface texture: Profile method. Terms, definitions and surface texture parameters (1997). **6.** ISO/DIS 25178-2: Geometrical product specification (GPS) - Surface texture: Areal - Part 2. Terms, definitions and surface texture parameters (2012). **7.** *G. Farkas:* Esztergált műszaki műanyag felületek mikrotopográfiai jellemzői, Ph.D. értekezés, (2010) 1-138. **8.** *J. Kundrák, I. Sztankovics, V. Molnár*: Accuracy and topography analysis of hard machined surfaces, Manufacturing Technology 21:4, (2021) 512-519. **9.** *S. Dzionk, B. Scibiorski, W. Przybylski*: Surface texture analysis of hardened shafts after ceramic ball burnishing, Materials vol. 204, (2019) 1-15. **10.** *A. Skoczylas, K. Zaleski:* Selected properties of the surface layer of C45 steel parts subjected to laser cutting and ball burnishing, Materials 3429, (2020) 1-19. **11**. *H. Luo, J. Liu, L. Wang, Q. Zhong:* Investigation of the burnishing process with PCD tool on non-ferrous metals, Int. J. Adv. Manuf. Technol. 25, (2005) 454-459. **12.** *G. Varga, B. Sovilj, I. Pasztor:* Experimental Analysis of Sliding Burnishing, Academic Journal of Manufacturing Engineering 11, (2013) 6-11. **13.** *MR. Stalin John, P. Suresh, D. Raguramand, BK. Vinayagam:* Surface characteristics of low plasticity burnishing for different materials using lathe, Arab J Sci Eng. 39, (2014) 3209–3216. **14.** *A. Akkurt:* Comparison of roller burnishing and other methods of finishing treatment of the surface of openings in parts from tool steel D3 for cold forming, Metal Science and Heat Treatment 53, (2011)145-150. **15.** *L. Luca, S. Neagu-Ventzel, I. Marinescu:* Effects of working parameters on surface finish in ball-burnishing of hardened steels, Precision Engineering 29, (2005) 253-256. **16.** *W. Grzeski, B. Kruszynski, A. Ruszaj:* Surface integrity of machined surfaces, Materials Science (2010) 143-179. **17.** *C. Cao, J. Zhu, T. Tanaka, D.N. Pham:* Invetsigation of corrosion resistance enhancemet for biodegradable magnesium alloy by ball burnishing process, Int. J. of Automation Technology 14, (2020) 175-183. **18.** *R. Horváth, Á. Drégely-Kiss, Gy. Mátyási:* The examination of surface roughness parameters in the fine turning of hypereutectic aluminium alloys, U. P. B. Sci. Bull., Series D 77, (2015) 205-216. **19.** *Varga, G.:* Effects of technological parameters on the surface texture of burnished surfaces, Key Engineering Materials 581, (2014), 403-408. **20.** *D. Toboła, P. Rusek, K. Czechowski, T. Miller, K. Duda:* New Indicators of Burnished Surface Evaluation – Reasons of Application, Metrol Meas Syst 12, (2015), 263–274. **21.** *G. Farkas, K. B Palásti, G. Kalácska:* Műszaki felületek mikrogeometriai vizsgálata, MTA Agrárműszaki Bizottság, XXIX. Kutatási és Fejlesztési Tanácskozás, (2005), 113-117. **22.** *R. Deltombe, M. Kubiakk, R. Krzysztof, M. Bigerelle:* How to select the most relevant 3D roughness parameters of a surface, Scanning 36, (2014), 150-160. **23**. 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: 01/06/22). **24.** *T.A. El-Taweel, M.H. El-Axir:* Analysis and optimization of the ball burnishing process through the Taguchi technique, International Journal of Advanced Manufacturing Technologies 41, (2009), 301-310. **25.** *K. B. Palásti:* Gépalkatrészek minősége. Tervezés, gyártás, minősítés. BMF BGK, Főiskolai jegyzet (2001) 10-25.

Вікторія Ференчик, Дьюла Варга, Мішкольц, Угорщина

ВПЛИВ ПРОЦЕСУ ВИГЛАДЖУВАННЯ НА АСИМЕТРІЮ І ЕКСЦЕС ПОВЕРХНІ ОБМЕЖЕНОГО МАСШТАБУ

Анотація: *У цій статті повідомляється про дослідження та аналіз шорсткості полірованих поверхонь із низьколегованого алюмінію з виділенням двох параметрів вертикальних відхилень профілю шорсткості від середньої лінії. Оздоблювальне накочування (галтівка) сталевими кульками - це одна з процедур холодного пластичного формування, в якому використовується механіка механічної деформації і яка підходить для обробки зовнішніх циліндричних поверхонь. Процес має багато переваг: зменшує шорсткість поверхні, підвищує мікротвердість, при цьому викликає залишкові напруження стиснення, покращує правильність форми і є екологічно чистим, оскільки не вимагає великої кількості рідини, що охолоджує, і мастила. У цьому дослідженні матеріалом циліндричних заготовок був низьколегований алюміній, оскільки розширення точних знань про оброблюваність кольорових металів є основною областю в багатьох галузях промисловості (автомобільній, авіаційній, аерокосмічній) через їх низьку щільність і хороші механічні властивості. Перед вигладжуванням виконували чистову токарну обробку. Процес вигладжування здійснювався на тому ж верстаті з використанням сферичного інструменту полікристалічного алмазу радіусом r = 3,5 мм. Кінематична в'язкість масла, що дозується вручну, становила = 70 мм2/с. За параметрами тривимірної амплітуди шорсткості було протестовано асиметрію та ексцес поверхні, обмеженої масштабом. За результатами вимірювань і розрахунків були зроблені такі висновки: найбільш сприятливу зміну шорсткості поверхні було відзначено у випадку поверхні з маркуванням №1, і подальші результати показують, що встановлення сили F = 15 Н з подачею f = 0,05 мм є найбільш сприятливим; результати чисельного експерименту також очевидно доводять, що вищі швидкість обробки і швидкість подачі несприятливо впливають на зміну шорсткості поверхні, оскільки у разі розміченої поверхні №5 всі параметри тривимірної шорсткості значно погіршилися. У плани авторів на майбутнє входить вивчення додаткових тривимірних параметрів шорсткості, щоб краще зрозуміти процес, що відбувається під час обробки.*

Ключові слова: *низьколегований алюміній; вигладжування; шорсткість поверхні; параметри 3D-топографії поверхні.*