Assessment of surface geometrical structure of hard to machine aerospace alloys after abrasive electro-discharge grinding (AEDG) and polishing

Ocena struktury geometrycznej powierzchni trudno obrabialnych stopów lotniczych po szlifowaniu elektroerozyjnym (AEDG) i polerowaniu

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In the article selected investigation results of surface morphology and geometrical structure after abrasive electro-discharge grinding (AEDG) and final polishing of samples made of hard machinable alloys used in aerospace industry has been presented. The machining parameters of samples have been determined and their surface geometrical structures after each stage of machining using 3D profiling have been estimated. Surface texture of samples has been assessed basing on microscope images.
KEYWORDS: hard machinable materials, abrasive electrodischarge grinding (AEDG), polishing, surface geometrical structure, surface texture

Abrasive electro-discharge grinding (AEDG) is a hybrid process, where mechanical energy synergy and spark discharges occur. This method solves the problems encountered in the treatment of hard-to-handle materials, in particular to obtain: high process efficiency, high dimensional shape and required surface condition [1, 2, 7]. Ease in controlling the electrical parameters of AEDG, including voltage and current, and time of electrical discharge, allows to control the process and results of the treatment.

The aim of the study was to determine the influence of processing conditions on AEDG and polishing on shaping of morphology and surface geometry (SGP) of selected alloys used in aviation industry such as Hastelloy X, Inconel 617 and Titanium 5553 β.

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These materials were obtained from the École Nationale Supérieure des Arts et Métiers (ENSAM) - Paris Tech de Cluny, and the test samples were prepared on an Accutex AU-300iA wire cutter at the Ergom Electrical Apparatus Factory.

Methodology and test conditions

The tests included evaluation of morphology and SGP of samples subjected to electro-discharge grinding (phase I) and finishing polishing (stage II). AEDG process (step I) was carried out on a test bench provided with: grinding machine type ECBT8 pulse generator GMP75 electrical discharge type, integrated measurement and control grinding parameters and a computer system for registration of the results of studies [2, 3].

Polishing process (phase II) was carried out on a 2-disc grinding polisher Phoenix Beta 2 Wirtz Buehler company, which was supplied by the laboratory of the Department of Manufacturing Engineering Technical University of Lodz. The grinding and polishing machine has a Vector Power Head semi-automatic grinding head with adjusting force in the range of 5 to 200 N and a 6-sided socket for fixing the sample with a diameter of 25 mm [4]. Polishing process of samples consisted of 5 treatments, which varied in size abrasive grains and a lubricant. The spatial 3D profiling method was used to determine the analyzed SGP parameters. Surface mapping of samples was made using the PGM IOS Krakow profiler on randomly selected areas of 1 mm × 4.8 mm. The *Rt, Ra, Rp, Rk* and *Rq* parameters were used to evaluate the surface geometry after machining.

Profilograms of the samples surface was performed with the following metrological parameters [5, 6]:
- sample step along the profile line: 0.5 μm,
- number of samples taken along the profile line: 9608,
- total profile line length: 4.804 mm,

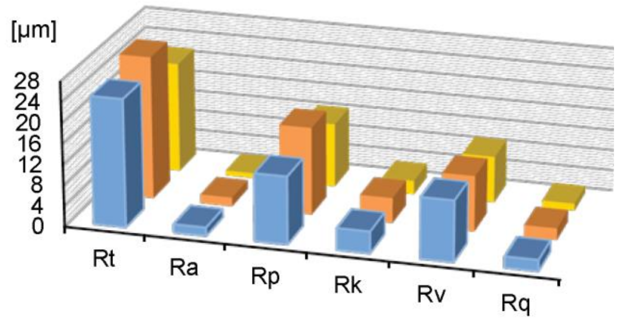
- distance between profile lines: 20 µm,
- number of profile lines in measuring set: 51.

SGP evaluation after electro-discharge grinding (AEDG)

The AEDG process was carried out with the parameters given in Table I. Exemplary results of SGP parameters measurement after AEDG are shown in fig. 1, and the surface morphology - in fig. 2.

TABLE I. Parameters of AEDG (CBN 125/100 M75 grinding wheel)

Kinetic parameters		Electric parameters	
Grinding speed v_s, m/s	30	Working voltage, V	150
Grinding wheel infeed a, µm	20	Working current, A	12
Table feedrate v_f, m/min	0,5	Pulse time, µs	32
		Break time, µs	63

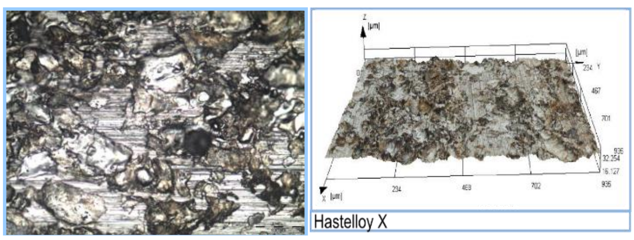


	Rt	Ra	Rp	Rk	Rv	Rq
Hastelloy X	24,75	1,58	13,03	4,16	11,72	2,12
Inconel 617	27,73	1,73	16,97	4,88	10,76	2,27
Titanium 5553 β	21,44	0,97	12,41	2,67	9,03	1,37

Fig. 1. Comparison of SGP parameters from aviation alloys after AEDG

Analysis of results indicates significant differences in the SGP pattern of samples from individual alloys after AEDG. It is significant that under the same AEDG grinding conditions, the most favorable SGP parameters were obtained for the Titanium 5553 β alloy.

The Olympus BX51M optical microscope (ENSAM, Cluny, France) and the Olympus DSX-HRSU optical profiler (ECAM, Lyon, France) were used to evaluate the surface morphology of samples (2D and 3D). The surface morphology of all ground samples revealed the presence of micro-craters and melting spots characteristic for the EDM processes.



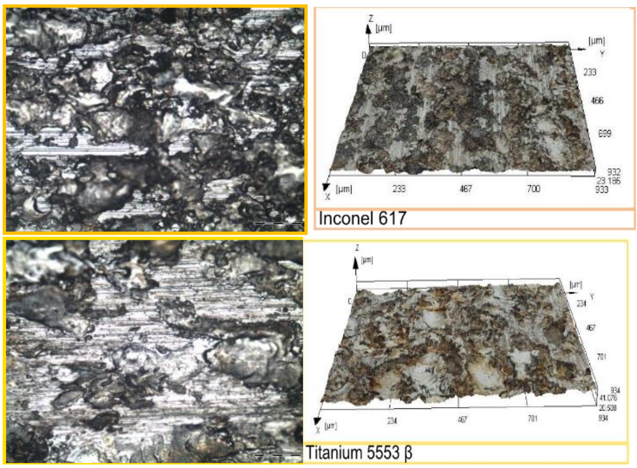


Fig. 2. Image of surface morphology of AEDG surface samples (in 2D and 3D)

It should be emphasized that, compared to conventional grinding, AEDG hybrid processing (using process parameters) increases the removal efficiency of the machining allowance and extends the grinding wheel life. The disadvantages of the AEDG process are the resulting micro-craters, which increase the roughness of the surface, and the effect of the additional heat flux from the spark discharges on the state of the surface layer [2, 3]. The way to limit these negative phenomena is to optimize the electrical parameters of the AEDG process (i.e. intensity and voltage of the electric current and the duration of the discharge pulse).

SGP evaluation of after polishing

The primary purpose of the second stage of the treatment was to remove the small thickness of the top layer damaged by the AEDG grinding process and to obtain the least surface roughness and the most favorable surface morphology. To do this, a 5-step polishing process was developed using modern abrasives from Buehler LTD, USA. Technological conditions of the 5-treatment polishing process are presented in the Table II. Sample results of surface morphology evaluation and SGP parameters measurement after the polishing process are shown in figs. 3-6.

Surface stereometric measurements were made using the PGM-1C IOS mechanical profilometer, while the 2D surface morphology images (fig. 3) were obtained using the Delta Optical imaging microscope IM-100 and 3D (fig. 4) using the Olympus DSX-HRSU optical profiler (ECAM, Lyon, France).

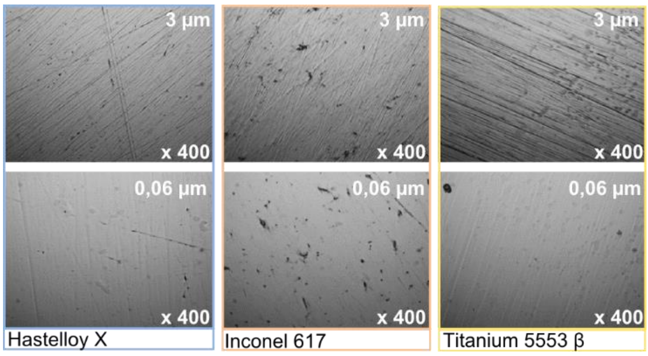


Fig. 3. Images of the plane surface morphology after finishing polishing (stage II) in 2D

TABLE II. Technological conditions of polishing

Stage	Type of abrasive (Buehler LTD)	Processing time, min	Pressing force, N/cm^2	Disc rotational speed, rpm
Stage I Preliminary polishing	SiC P600 (grain size 26 µm)	4	7	300
	SiC P1200 (grain size 15 µm)	2		
	SiC P 2500 (grain size 10 µm)	1		
Stage II – Finishing polishing	Poly-crystalline diamant solution MetaDi Supreme, 3 µm + abrasive fabric VerduTex	3	3	150
	Coloidal suspension SiO_2 MastreMet 2, 0,06 µm + abrasive fabric ChemoMet	3		100

The analysis of the results confirmed the significant improvement of SGP parameters from the alloys after subsequent polishing operations. A clear improvement of the surface morphology of treated alloys was also obtained after final finishing polishing (figs. 5-6).

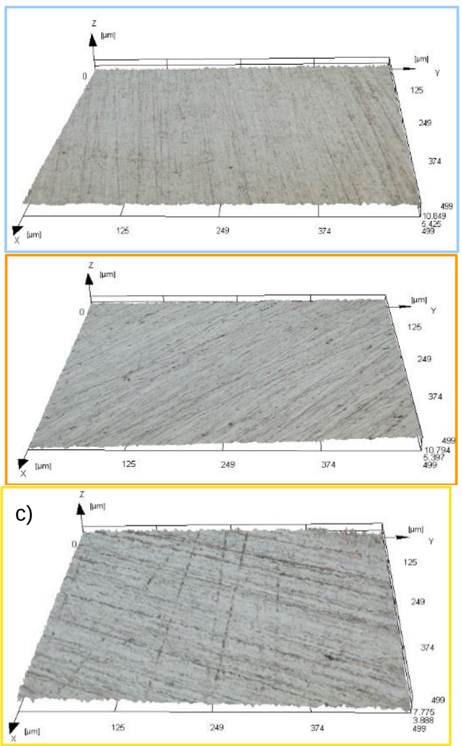
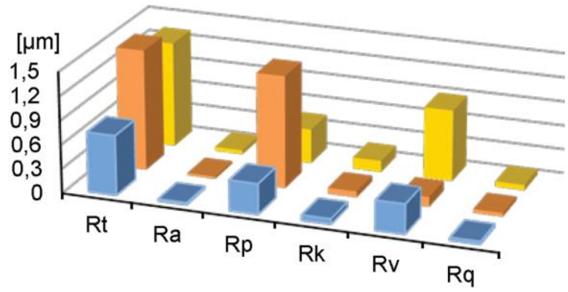
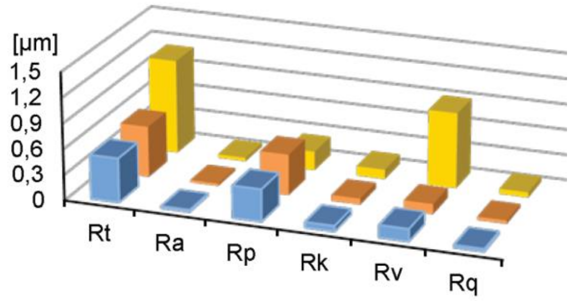


Fig. 4. Surface morphology (in 3D) of aviation alloys after finishing polishing (stage II) with SiO_2 solution - 0.06 µm: a) Hastelloy X, b) Inconel 617, c) Titanium 5553 β



	Rt	Ra	Rp	Rk	Rv	Rq
Hastelloy X	0,738	0,022	0,374	0,063	0,364	0,033
Inconel 617	1,515	0,028	1,39	0,074	0,125	0,046
Titanium 5553 β	1,313	0,05	0,427	0,141	0,886	0,069

Fig. 5. Comparison of SGP parameters of tested alloys after finishing polishing (stage II), solution with diamond particles of 3 µm



	Rt	Ra	Rp	Rk	Rv	Rq
Hastelloy X	0,516	0,021	0,374	0,062	0,142	0,029
Inconel 617	0,599	0,027	0,48	0,07	0,119	0,04
Titanium 5553 β	1,112	0,042	0,222	0,113	0,889	0,061

Fig. 6. Comparison of SGP parameters of tested alloys after finishing polishing (stage II); solution with SiO_2 grains - 0.06 µm

The images of these surfaces show a gradual decrease in the depth of the machining traces (micro-crters and scratches) after the AEDG process and the appearance of cross-cutting shallow traces for polishing. Of the 3 tested alloys, the titanium alloy was the most difficult to process, while the treatment of Hastelloy X and Inconel 617 alloys was similar, as evidenced by similar SGP parameters and surface morphology.

Conclusions

The studies confirmed the usefulness of AEDG and finishing polishing technology for the high-quality surface treatment of hard-to-melt aviation alloys. Deep machining traces, micro-craters and surface melted spots are removed in the 5-step polishing process.

In order to know the full characteristics of the tribological properties of the surface layer, it is advisable to continue the work aimed, among others, at studying the temperature distribution in the surface layer, especially in the AEDG process.

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