Abrasive flow machining of nickel based super-alloys

Obróbka przetłoczno-ścierna nadstopów niklu

DOI: https://doi.org/10.17814/mechanik.2017.10.137

RAFAŁ ŚWIERCZ
DOROTA ONISZCZUK-ŚWIERCZ *

Abrasive flow machining (AFM) is one of the non-conventional methods of the surface finishing. The material is removed by the flow of pressurized abrasive paste between the machined surfaces. The use of a flexible tool allows for finishing surfaces with complex geometry. The article presents results of experimental investigation on finishing surface topography of nickel-based super-alloys. Samples were pretreated by the electrical discharge machining. The results of the study indicate the possibility of significant surface roughness improvement after the EDM with the AFM finishing.

KEYWORDS: abrasive flow machining (AFM), surface roughness, Inconel

In recent years, many industries (e.g. in the energy industry, aerospace or space) significantly increased the use of high-temperature alloys, called super-alloys. Materials in this group include hot nickel alloys, which, even at high temperatures, retain their strength properties. Treatment of these super-alloys in many cases requires the use of the electrical discharge machining and wire cutting (EDM, WEDM). Such processes consist in shaping the geometry of the workpiece due to electrical discharges between the electrodes. Physical phenomena determined by the EDM interact thermally, mechanically and chemically with the workpieces. The heat flux causes local melting and evaporation. The heat generated results in local phase transformation, thus changing the microstructure of the material and the layer at the surface may appear in the tensile stress, rbesulting in micro-fractures [10, 12]. Due to disadvantageous properties of the surface layer of the parts subjected to the EDM, it is necessary to apply additional finishing to ensure the surface of the desired properties. Commonly used types of finishing – such as grinding, lapping, polishing or container treatment – are ineffective in the case of inaccessible places of geometrically complex parts, resulting from the kinematics of these processes and the geometry of the tools used [5–8, 11]. Abrasive flow machining (AFM) – is one of the surface finishing methods, consisting of removing the material from the cyclical flowing – 1 or 2-way – of abrasive paste (fig. 1).

The use of a flexible tool based on the viscoelastic polymer of the polyborisiloxane type enables the machining of complex shapes, including hard-to-reach areas. These possibilities predestine the abrasive flow treatment for surface finishing after the electrical discharge machining. The effect of the treatment depends on many factors determining the conditions and parameters of the process (fig. 2) [1–4, 9, 13].

* Dr inż. Rafał Świercz (rsw@meil.pw.edu.pl), dr inż. Dorota Oniszczuk-Świercz (doo@meil.pw.edu.pl) – Instytut Technik Wytwarzania, Wydział Inżynierii Produkcji Politechniki Warszawskiej

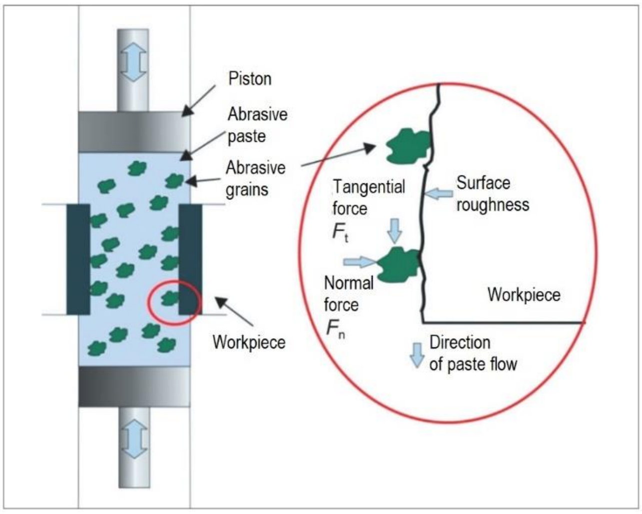

Fig. 1. Diagram of 2-way flowing the abrasive paste

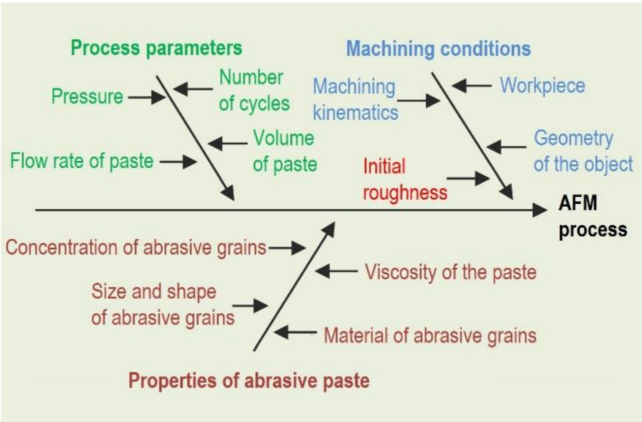

Fig. 2. Factors determining the AFM process

Purpose of research

The aim of the study was to determine the influence of the abrasive flow machining on the surface topography characteristics after the EDM of Inconel 718. The properties of surface topography significantly influence the functional properties of the machined parts, among others, the friction processes between the cooperating elements and their wear, as well as the deformation and the contact strength.

Under industrial conditions, the EDM process is divided into several stages – from roughing to subsequent reduction of the discharge energy parameters in the final step. Process efficiency drops sharply for parameters corresponding to the finishing (removal of the 0.2 mm allowance can take up to 2 hours). In order to determine the possibility of reducing the time needed for the erosion process, the use of AFM finishing instead of both EDM roughing and finishing was analyzed.

Experimental studies

In the experimental research upon the AFM processing, samples were taken from Inconel 718, pre-treated electro-discharge with parameters corresponding to roughing (current I = 8A, discharge voltage U = 50 V, pulse time t_{on} = 75 µs, break time t_{off} = 50 µs and finishing (I = 1.7 A, U = 50 V, t_{on} = 75 µs, t_{off} = 50 µs). The research was conducted under the following conditions:

- 2-way machining,
- Abrasive paste with SiC grain No. 80,
- number of flows n = 25,
- slot width s = 0.5 mm,
- flow pressure in the actuator p=7 MPa.

During testing, the pressure in the cylinder chamber and the change in the temperature of the abrasive paste were recorded.

Results

The main parameters determining the micro-grinding process that affects the surface roughness and material removal rate are the forces acting on the abrasive grains resulting from the throttling of the abrasive paste along the surface to be machined. The increase in the number of flow cycles results in lower roughness, which is not linear. This is due to the increase in temperature of the abrasive paste (fig. 3a), which leads to a change in the viscosity of the abrasive paste and the drop of the flow pressure (fig. 3b).

Surface geometry structure (SGP) studies were conducted on the FORM TALYSURF Series 2 Scanner by Taylor Hobson Ltd. Fig. 4 and fig. 5 show stereometric images and profilographs of the samples subjected to the EDM and the EDM + AFM.

The topography of the surface after the EDM shows the overlapping traces of individual electrical discharges and has a point-like, isotropic structure. The AFM finishing makes significant changes to the construction of stereometric analysis.

The arithmetic mean deviation of the roughness profile for sample 1 after the EDM roughing (fig. 4a) is Sa=7.3 µm and the mean square deviation of surface roughness Sq = 9.21 µm.

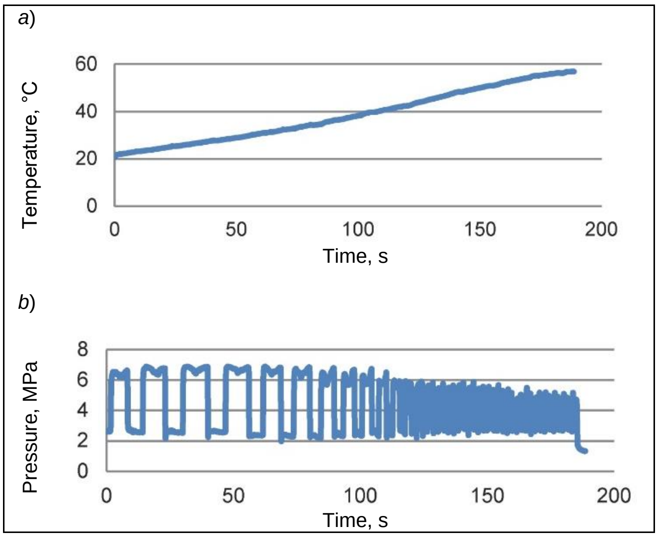

Fig. 3. Temperature changes (a) and pressure (b) during the abrasive flow process

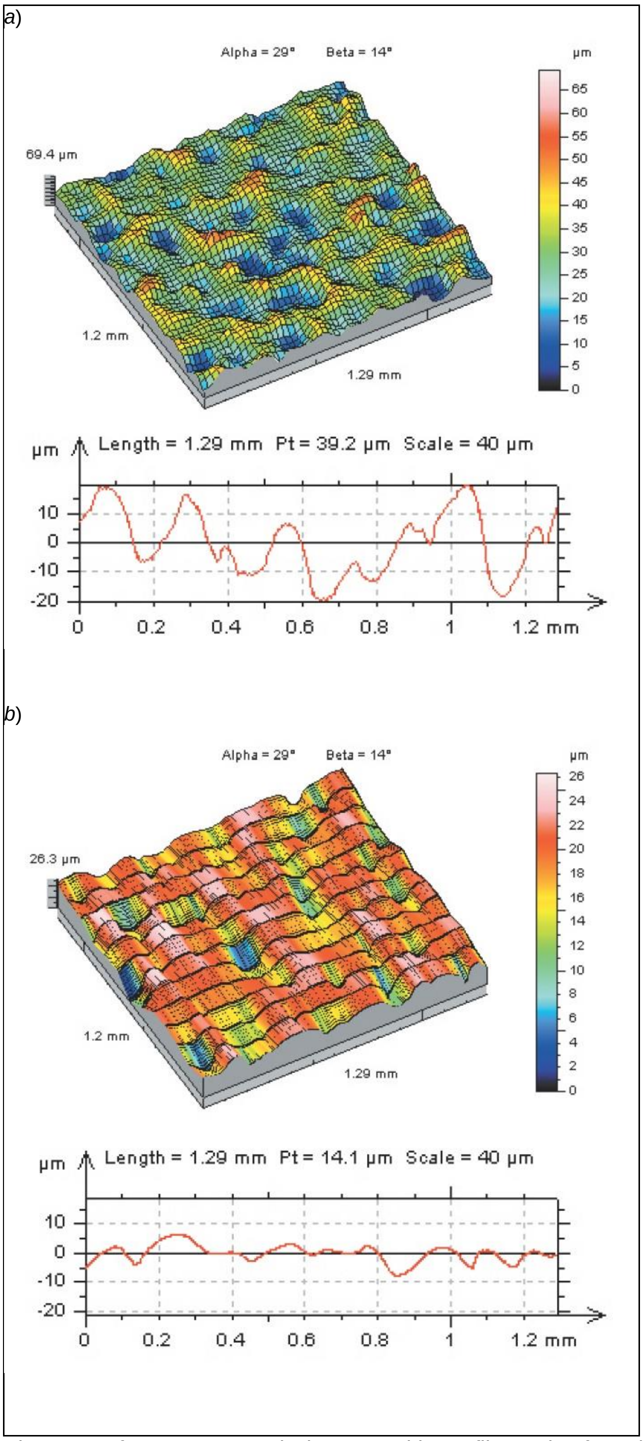

Fig. 4. Surface stereometric images with profilographs for: *a*) rough EDM processing, *b*) finishing EDM + AFM

The difference between St = 69.4 µm (the height of the inequality between the highest and the lowest point) and Sz = 56.7 µm (ten-point unevenness) is more than 10 µm, which indicates the existence of single craters of much greater depth. The surface density of the local peaks is Sds = 603 pks/mm^2. For the sample after the EDM+AFM (fig. 4b), significant differences in the values of individual parameters were observed with respect to the EDM process. The 3D height parameters – Sa = 2.76 µm and Sq = 3.64 µm – are approximately 2.5 times smaller. There was a change in surface density of local peaks (Sds = 1324 pks/mm^2) and the difference between St (26 µm) and Sz (26.3 µm) values was small. This demonstrates the uniformity of the abrasive paste machining of the whole surface and the reduction of the height of the individual asperity peaks.

The arithmetic mean deviation of the *Sa* roughness profile for sample 2 after the EDM finishing (fig. 5a) is 1.31 μm and *Sq* = 1.64 μm. The difference between *St* = 17.9 μm and *Sz* = 16 μm is small, and the surface density of local peaks is *Sds* = 2129 pks/mm^2, indicating the presence of a large number of even craters throughout. For the sample after EDM finishing + AFM (fig. 5b), a significant change was observed in the construction of the topography. Parameters *Sa* = 0.21 μm and *Sq* = 0.27 μm are about 6 times smaller. The *Sds* parameter is 4767 pks/mm^2. The surface density of asperity peaks is more than 2 times the EDM. The values bof *St* = 2.62 μm and *Sz* = 1.94 μm indicate the presence of individual pits of different depths. The topography of the machined surface is characterized by a change in structure from isotropic to directional.

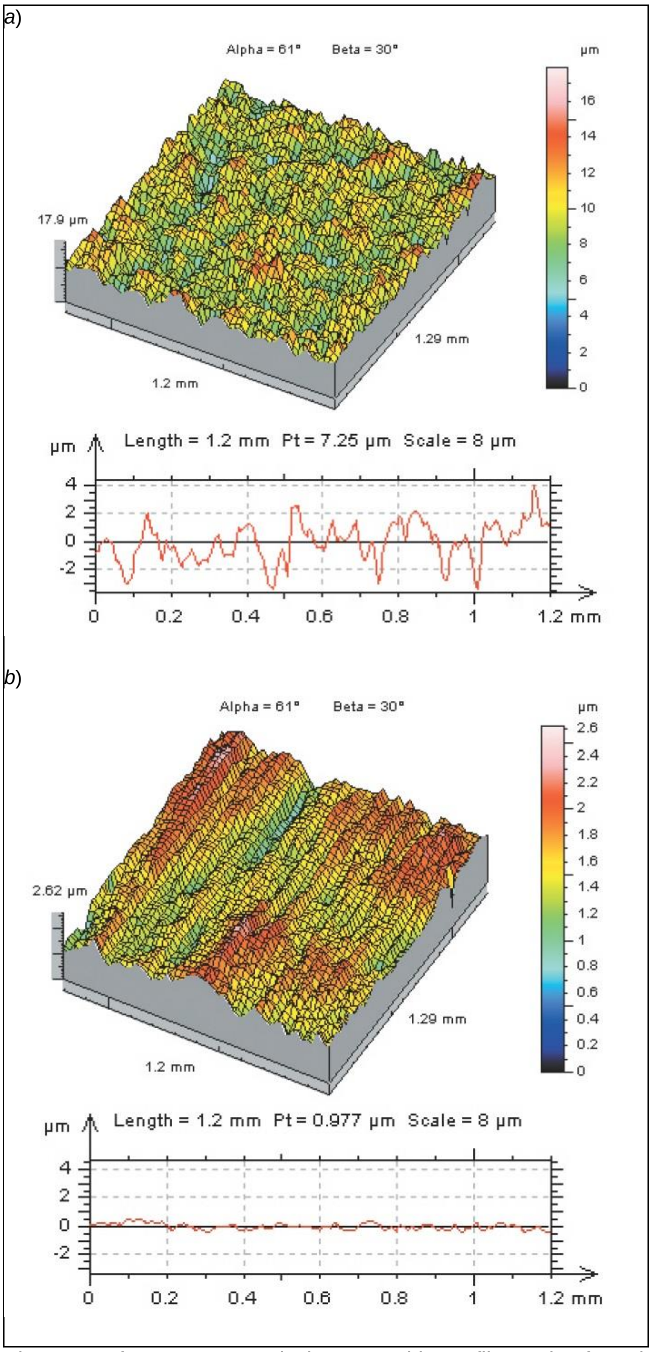

Fig. 5. Surface stereometric images with profilographs for: *a*) EDM finishing, *b*) finishing EDM + AFM

Conclusions

Experimental studies have shown that the use of abrasive flow machining can reduce the surface roughness of Inconel 718 after the EDM several times, and the resulting stereometric characteristics are dependent on the initial roughness of the samples.

An important aspect in the design of electro-erosion treatment processes is the ability to quickly and clearly improve the stereometric features of machined parts with the parameters corresponding to the EDM roughing. This can reduce the number of additional finishing passes and thus reduce machining time.

The versatility of the tool that adapts to the machined geometry in the abrasive flow machining determines the high potential of this technology when used as a finishing after the electrical discharge machining.

REFERENCES

1. Bähre D., Brünnet H., Swat M. “Investigation of one way abrasive flow machining and in-process measurement of axial forces”. *Procedia CIRP*. 1 (2012): pages 419–424.
2. Bremerstein T. et al. “Wear of abrasive media and its effect on abrasive flow machining results”. *Wear*. 342–343 (2015): pages 44–51.
3. Dąbrowski L., Świercz R., Oniszczuk-Świercz D. „Mikroobróbka wykończeniowa – obróbka przetłoczno-ścierna”. *Mechanik*. 8–9 (2016): pages 1132–1133.
4. Gudipadu V. et al. “Simulation of media behaviour in vibration assisted abrasive flow machining”. *Simulation Modelling Practice and Theory*. 51 (2015): pages 1–13.
5. Kacalak W., Tendecka K. „Analiza procesów mikrowygładzania stopów niklowo-chromowych z wykorzystaniem wyników badań topografii powierzchni i cech powstających mikrowiórów”. *Mechanik*. 8–9 (2016): pages 1172–1173.
6. Kacalak W., Rypina Ł., Tandecka T., Bałasz B. „Modelowanie w środowisku Ansys procesów mikroskrawania materiałów o różnych właściwościach”. *Mechanik*. 8–9 (2016): pages 134–136.
7. Kacalak W., Szafraniec F., Budniak Z. „Podstawy doboru parametrów szlifowania z uwzględnieniem liczby ziaren kształtujących określony fragment powierzchni”. *Mechanik*. 8–9 (2016): pages 1182–1183.
8. Burek J., Babiarz R., Sałata M., Płodzień M. „Wpływ siły szlifowania na odkształcenia sprężyste długich frezów pełnowęglikowych”. *Mechanik*. 8–9 (2015): pages 709/55–58.
9. Kenda J., Pusavec F., Kermouche G. “Surface integrity in abrasive flow machining of hardened tool steel AISI D2”. *Procedia Engineering*. 19 (2011): pages 172–117.
10. Oniszczuk-Świercz D., Dąbrowski L., Świercz R., Marczak M. „Konstytuowanie warstwy wierzchniej Inconelu 718 po wycinaniu elektroerozyjnym”. *Mechanik*. 4 (2015): pages 71–74.
11. Spadło S., Bańkowski D. „Badanie wpływu geometrii przedmiotów obrabianych na efekty obróbki luźnym ścierniwem”. *Mechanik*. 8–9 (2016): pages 1156–1157.
12. Świercz R., Oniszczuk-Świercz D. „Wpływ parametrów obróbki elektroerozyjnej na właściwości użytkowe stali o wysokiej przewodności cieplnej”. *Mechanik*. 1 (2015): pages 29–34.
13. Uhlmann E., Mihotovic V., Roßkamp S., Dethlefs A. “A pragmatic modeling approach in Abrasive Flow Machining for complex-shaped automotive components”. *Procedia CIRP*. 46 (2016): pages 51–54.