Tests of finishing work of cut parts using loose abrasive fittings

Badania obróbki wykończeniowej elementów wykrawanych z wykorzystaniem luźnych kształtek

SŁAWOMIR SPADŁO
DAMIAN BAŃKOWSKI
MIECZYSŁAW MAMLA *

DOI: https://doi.org/10.17814/mechanik.2017.11.166

The paper presents an example of an unconventional finishing method using loose abrasive fittings known as vibration machining. Typical machine parts in the form of metal supports have been the workpieces. Particular attention has been paid to rounding the edges, reducing the roughness of the surface, and improving its reflectivity. The influence of basic process parameters on the achieved results has been determined. Tests allowed to determine the mass loss as a function of machining time. Due to observations using the Taylor Hobson Talysurf CCI Lite optical profilometer, it was possible to accumulate and to analyze results in a form of basic parameters of surface geometric structure.
KEYWORDS: vibratory machining, finishing, surface roughness, surface layer

In times of high economic growth, the demand for products continues to grow. Manufacturers are constantly striving to reduce production costs, shorten execution time of finished products, and above all – to increase the competitiveness of products by raising their aesthetics. Visual features often affect the decisions of potential consumers. One of possibility to achieve the desired geometric characteristics of the surface structure is finishing with loose abrasive fittings in container smoothing devices. The paper presents an example of such treatment application using a loose fitting in a vibrating container, i.e. vibratory machining.

Vibratory machining

Process of chemical-mechanical finishing using loose fittings in vibrating containers is referred to as vibratory machining [1–3]. Often are also used terms such as vibratory machining, rotofinish, tumbling, troweling and micro mass finishing [4–6]. Vibro-abrasive machining is used as a finishing – for removing burrs from the edges or smoothing the surface [7, 8]. The process is carried out in sealed containers, containing a mixture of in the form of workpieces and working medium (in the form of appropriately selected abrasive or polishing fittings), and working fluid for machining [9, 10]. Vibratory movements of the machine working container forces moving relative to one another abrasive shapes and machined parts [11–14]. This causes the interaction of the materials contained in the tumbler - container and abrasion of the surface irregularities [15, 16]. Vibro-abrasive machining has been widely used in many industries, in particular for finishing small pieces of complex geometry [17–21].

* Dr hab. inż. Sławomir Spadło, prof. PŚk (sspadlo@tu.kielce.pl), mgr inż. Damian Bańkowski (dbankowski@tu.kielce.pl) – Zakład Materiałoznawstwa i Technologii Amunicji, Politechnika Świętokrzyska; mgr inż. Mieczysław Mamla (m.mamla@mesko.com.pl) – Zakład Budowy Maszyn i Narzędzi Specjalnych Mesko S.A.

Machining parameters

Rollwasch SMR-D 25 vibratory machining equipment was used in the study. The active part of the batch was abrasive fittings PB 14 KT with polyester binder. Due to their high cutting ability, they are intended for deburring processes [13]. In addition, as a support for polishing and surface bleaching, a ME L100 A22/N series liquid was used. The process parameters are summarized in Table I. The aim of this study was to evaluate the loss of mass and the characteristics of surface geometric parameters (SGP) of the structure as a function of smoothing time.

TABLE I. Process parameters

Device	SMR-D 25
Abrasive fittings	PB 14 KT
Support fluid	ME L100 A22/NF
Frequency of vibration, Hz	2500
Processing time, min	20, 40, 60, 80, 100, 120

Results

In technical terms, the analysis of vibration smoothing technology and manual methods is primarily to compare the results of surface tests obtained by these methods. Experimental studies were conducted for samples of C45 steel having the dimensions given in fig. 1.

Samples, in the form of rings, were made by cutting. The samples were grouped in lots of 5 pieces. In order to determine the loss of mass of samples, they were weighed. Individual samples were extracted at equal intervals of 20 min. Processing time of the last sample batch was 120 min. As a result, 6 measurement results were obtained. The mass of samples was re-measured then. Results of the measurements are summarized in Table II.

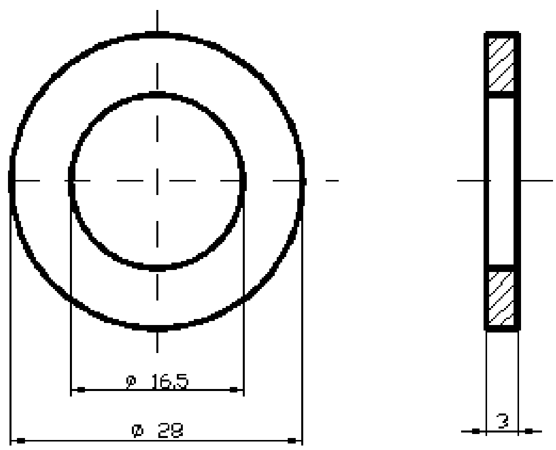

Fig. 1. Shape and dimensions of samples used for the tests

TABLE II. Results of mass loss measurement depending on machining time

Machining time, min	Δ*m*, mg	*MMR*, ‰	Δ*m/t*, mg/h	Δ*V/t*, mm^3/h
20	24.6	0.58	73.8	9.40
40	31.2	0.72	46.8	5.96
60	43.4	1.01	43.4	5.53
80	56.4	1.31	42.3	5.39
100	69.3	1.60	41.6	5.30
120	82.4	1.92	41.2	5.25

Designations:
Δ*m* – loss of mass.
MMR – weight loss related to mass before machining.
Δ*m/t* – mass loss related to time – mass yield.
Δ*V/t* – volumetric loss related to time – volume yield

Analyzing results of mass loss measurement, contained in the table II, it can be seen that – as expected – mass of samples decreases with the machining time. For details machining of 29 minutes, the weight loss of workpieces was 24.6 mg, while in the case of 120 minutes machining, on average the loss was more than three times higher – it was 82.4 mg. In order to estimate the quantitative changes in the mass of the samples, a mass loss was determined – material removal rate (MRR). Weight loss, expressed in mg, was calculated on the basis of mass loss relative to mass (parts) prior to the smoothing operation. Similarly to the machining time equal to 20 minutes, the weight decreased by 0.58‰, and for the time 120 min – about 1.92‰. Analysis of the mass yield parameter indicates that after the first 20 minutes of the process, value of Δ*m/t* is 73.8 mg/hr. This is double more the value as achieved at subsequent stages of the process. Analogous situation is observed for a volumetric capacity of Δ*V/t* – for the first 20 min is 9.40 mm^3/hour, and the subsequent processing stages reach the values in the range of 5.5 mm^3/hour. Thus, it is possible to conclude that in the first stage of removal, the most sharp edges, burrs and the largest surface irregularities are removed. To illustrate the change in weight of sample batch was made graph (Figure 2) showing a loss of mass in the function of treatment time. As it can be seen, over time, the mass loss is increasing and it is almost a linear relationship. To determine what was the change in the mass loss of individual samples, relevant results from the Table II should be refer to the number of samples in the batch (in the analyzed case, the batch contained 5 samples). Also changes of weight loss between consecutive 20-min periods of the machining times were calculated (Table III).

It can be seen that the greatest loss of weight takes place during the first 20 minutes of the process – in this case, it amounted to 4.92 mg. For the next period, i.e. from 20 to 40 minutes, the difference in mass before and after machining was almost nearly four times less than during the first period. Successive periods have a nearly linear relationship in weight loss for the machining periods – the weight loss of the test piece reaches a value in the range of 2.5 mg. This confirms that in the first machining step, the largest number of burrs and surface irregularities are removed.

The vibratory machining is carried out using relatively simple technological devices. In many cases, this method can be a solution to the technological problems related to finishing of complex (complicated shapes) machine parts. The results of surface roughness as a function of the processing time allowed for graph (fig. 3). In order to approximate the results, the type of exponential trend line was applied, which is the best approximation based on the changes of surface roughness as a function of the smoothing process duration.

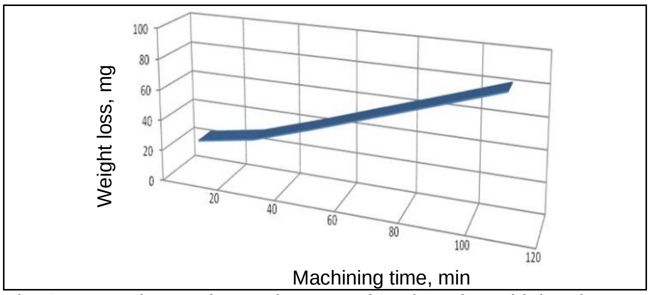

Fig. 2. Dependency of mass loss as a function of machining time

TABLE III. Mass loss of individual samples and mass loss in subsequent time intervals

Machining time, min	Weight loss, mg	Mass loss in consecutive time intervals (20 min), mg
20	4.92	4.92
40	6.24	1.32
60	8.68	2.44
80	11.28	2.60
100	13.86	2.58
120	16.48	2.62

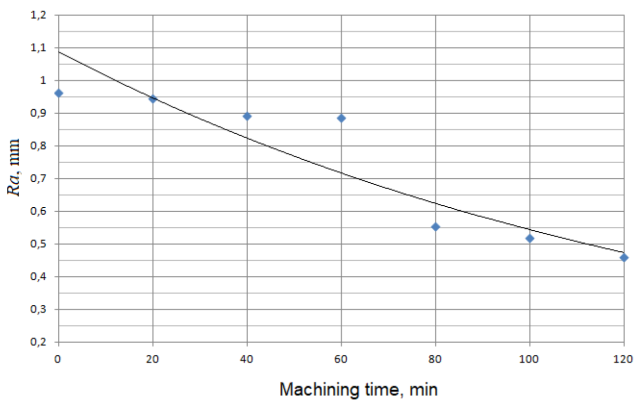

Fig. 3. Dependence of surface roughness Ra from machining time

Geometric structure of the surface

Initial evaluation of surface topography was made using the microscopic technique (macroscopy). Based on the macroscopic observation of the surface, irregularly spaced scratches may be observed on the surface oriented at random direction. In addition, traces of plastic processing (rolling) on the surface from which the test rings were made are visible on the surface. When planning the finishing treatment, you need to ensure the quality of the starting materials from which the items will be made, because the originating defects from previous manufacturing steps, they can extend the smoothing time and increase processing costs.

The Talysurf CCI Lite optical profiler from Taylor Hobson was used to measure the 3D topography of the surface. The 3D analysis of the surface of rings treated with vibratory machining method allows to state (fig. 4) that the arithmetic mean value of surface area *Sa* [22] of 0.42 µm was obtained by treating the sample for 120 min, while for the sample in the initial state, the parameter amounted to 95 µm. Also, the maximum height of the surface *Sz* decreased from 13.40 µm to 7.57 µm after 120 min. The SGP directional distribution in a polar coordinate system is illustrated in figure 5. The distribution of irregularities before the smoothing process (Fig. 5a) indicates that the SGP is unidirectional

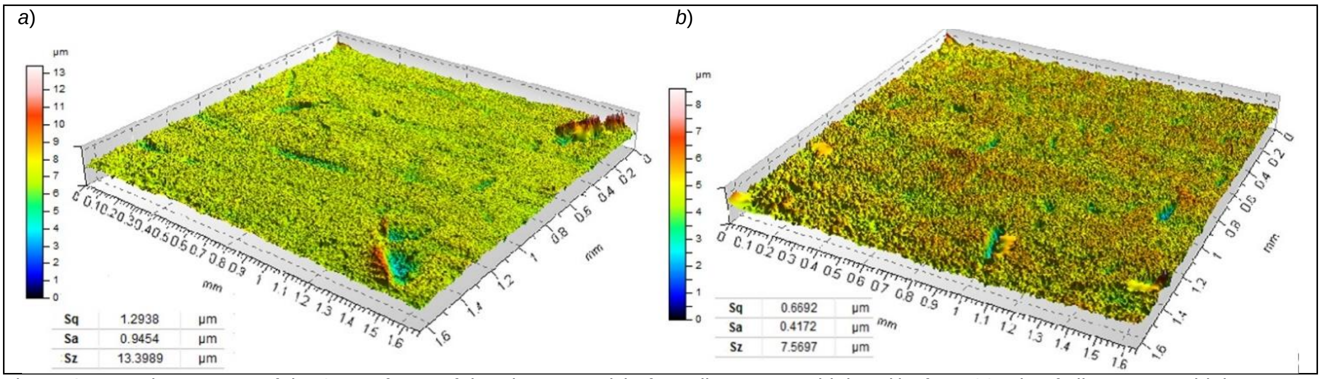

Fig. 4. Geometric structure of the 3D surfaces of the elements: *a*) before vibratory machining, *b*) after 120 min of vibratory machining

- the analysis revealed micro-geometric features of the surface resulting from the impact of the tools durring the rolling process (these are tracks parallel to the direction of rolling). As a result of interactions of fittings in the container smoothing conditions (it should be emphasized that in volume of the batch, the impact of the abrasive grain with the machined surface is random) the undetermined (random) geometric structure of the surface is constituted. An example polar distribution of surface after vibratory smoothing is shown in Fig. 5b. The polar graph analysis indicates that there is an even distribution of directional micro-unevenness. It can be concluded that the surface after machining using loose fittings is characterized by isotropic geometric structure – there are no preferred orientation and direction of inequalities.

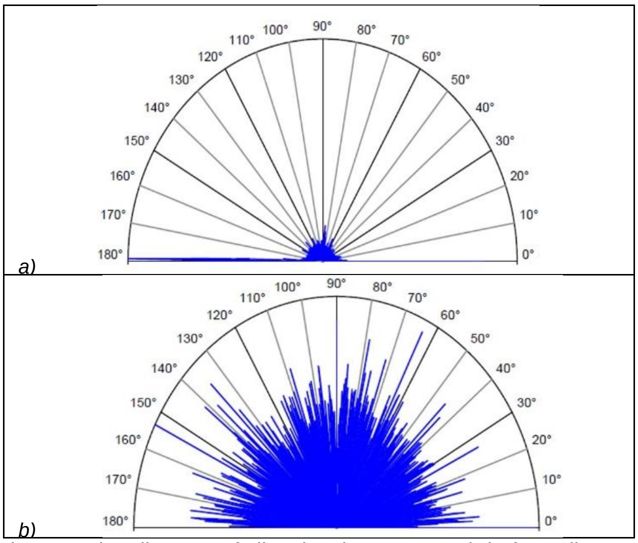

Fig. 5. Polar diagram of directional structure: *a*) before vibratory machining– isotropy approximately 10%, *b*) after 120 min vibratory machining – isotropy about 77%

Conclusions

Vibratory machining using loose abresive fittings is an effective way of finishing – both simple and more complex (in terms of geometry) elements.

The largest mass loss, and the highest smoothing effect, is achieved at the initial stage of the smoothing process. For the first 20 min of machining, this loss for a single sample was 4.92 mg. A further process is characterized by a linear mass loss as a function of the machining time. Weight loss in the next 20 minutes is about 2.5 mg.

Surface roughness studies have confirmed that the *Ra* value can be reduced approximately twice from 0.97 µm to 0.46 µm due to the appropriate machining parameters.

As a result of the vibro-abrasive machining, a surface with random distribution of micro-unevenness is obtained.

REFERENCES

1. Bańkowski D., Spadło S. “Influence of the smoothing conditions in vibro-abrasive for technically dry friction the parts made of steel X160CrMoV121”. *Metal 2016: 25th Anniversary International Conference on Metallurgy and Materials* (2016): pages 1019–1024.
2. Bańkowski D., Spadło S. “The application of vibro-abrasive machining for smoothing of castings”. *Archives of Foundry Engineering*. 17, 1 (2017): s. 169–173, DOI: 10.1515/afe-2017-0031.
3. Bańkowski D., Spadło S. “Influence of the smoothing conditions in vibro-abrasive finishing and deburring process for geometric structure of the surface machine parts made of aluminum alloys EN AW-2017A”. *Metal 2015: 24th International Conference on Metallurgy and Materials* (2015): pages 1062–1068.
4. Davidson D.A. “Mass finishing processes”. *2002 Metal Finishing Guidebook and Directory*. New York: Elsevier Science, 2002.
5. Rao Suren B. “Repair of aircraft transmission gears via isotropic superfinishing”. *Gear Technology*. May (2009).
6. Brinksmeier E., Giwerzew A. “Hard gear finishing viewed as a process of abrasive wear”. *Wear.* 258 (2005).
7. Harasymowicz J., Wanatuch E. „*Obróbka gładkościowa*”. Wydawnictwa Politechniki Krakowskiej, 1994.
8. Górski E. „*Obróbka gładkościowa*”. Warszawa: WNT, 1963.
9. Woźniak K. „*Obróbka powierzchni w wygładzarkach pojemnikowych*”. Warszawa: WNT, 2017.
10. Nowicki B., Stefko A., Szulc S. „*Obróbka powierzchniowa*”. Warszawa: PWN, 1970.
11. Filipowski R., Marcinak M. „*Techniki obróbki mechanicznej i erozyjnej*”. Warszawa: Oficyna Wydawnicza Politechniki Warszawskiej, 2000, pages 304–308.
12. Oryński F., Synajewski R., Bechciński G. „Fizyczny model szlifowania wibracyjnego płaszczyzn w kierunku poprzecznym”. *Mechanik*. 86, 1 (2013): pages 30–34.
13. www.rollwasch.it/en, Vibro Dry Experience PL, Rollwasch Italiana S.p.a (dostęp: 18.04.2017).
14. Kacalak W., Tandecka K. “Effect of superfinishing methods kinematic features on the machined surface”. *Journal of Mechanical Engineering*. 4 (2012): pages 35–48.
15. Starosta R. „Obróbka powierzchniowa”. Gdynia: Wydawnictwo Akademii Morskiej w Gdyni, 2008.
16. Bańkowski D., Spadło S. “Investigations of influence of vibration smoothing conditions of geometrical structure on machined surfaces”. *4th International Conference Recent Trends in Structural Materials.* COMAT 2016. T. 179, (2017), DOI: 10.1088/1757-899X/179/1/012002.
17. Matuszewski M. „Nośność powierzchni a rodzaj jej obróbki”. *Tribologia.* 6 (2011): pages 143–150.
18. Gillespie L.K. “*Deburring and Edge Finishing Handbook*”. Society of Manufacturing Engineers, 1999.
19 Aurich J.C., Dornfeld D., Arrazola P.J., Franke V., Leitz La S. “Burrs – Analysis, control and removal”. *CIRP Annals – Manufacturing Technology.* 58 (2009): pages 519–542.
20. Xiao L., Rosen B.-G., Naser Amini, Nilsson P.H. “A study on the effect of surface topography on rough friction in roller contact”. *Wear.* 254 (2004): pages 1162–1169.
21. Mikolajczyk T., Borboni A., Mackowski D., Matuszewski M. “Example of tool with two numerical controlled axes”. *Applied Mechanics and Materials*. 772 (2015): pages 224–228.
22. Adamczak S. „Pomiary geometryczne powierzchni”. Warszawa: WNT, 2009. ■