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SEQUENTIAL TREATMENT PROCESS IN A ROTARY CONTAINER POLISHING MACHINE WITH PERIODIC WORKPIECE LOCATION CHANGES IN WORKING ABRASIVES AREAS

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Abstract: This paper presents the process of a 3-step machining process involving pre-treatment, smoothing and polishing, placing the workpiece in different energy levels of the working load in a rotary-cascade container smoother, by moving it towards the radial direction of the working chamber of the smoother. Studies show the ability to control the course of pre-treatment, smoothing and finishing intensity, both in terms of process parameters and treatment time. Such a structure of the machining process, it also allows you to influence the structure geometry of the machined surfaces in successive stages of machining, and consequently on the final quality. The proposed organization and structure of the process allows for the creation of a new one surface treatment strategy.

Keywords: mass finishing, active holder, stainless steel, surface roughness

1. INTRODUCTION

In relation to container smoothing processes, as with many other machining processes, it is increasingly expected to reduce machining time and energy consumption. This is particularly important for high-capacity chamber smoothers and continuous machining smoothers. The basic condition for meeting these expectations, however, is to ensure the required technological quality of the treated surfaces and their repeatability in serial production.

In the rotational-cascade container machining the certain types of workpieces with the appropriate abrasive media, the energy efficiency of the process depends primarily on the parameters and processing time. The energy intensity of machining increases with the desire for less and less roughness of the workpiece surface, which is associated with the extension of the machining time and the possible transition to a multi-stage process, combined with a changes in the type of working fittings.

The work carried out at the Department of Production Engineering of the Koszalin University of Technology confirms that in the case of machining workpieces in handles, there are also many additional possibilities to control the intensity and surface condition of workpieces processed in rotary-cascade container smoothers. For this purpose, special tooling of the workpiece handles is used, which makes it possible to give the workpiece additional movements. These are vibrational, rotational movements and their various types of mutual associations. This allows to control the mechanism of shaping the geometric structure of the treated surface as a result of changing the share of elementary working phenomena, which include: micro-cutting, cratering, scratching and reeling. In addition, it is possible to define the surface topography in a specific way by orienting the processing traces, their shaping, embedding and compaction. Possibilities in this regard are provided by the orientation of the workpieces in specific zones of the work charge, characterized by a specific machining potential, and thus the processing intensity [4,5,6,7].

This paper presents the process of a 3-step machining process involving pre-treatment, smoothing and polishing, placing the workpiece in different energy levels of the working load in a rotary-cascade container smoother, by moving it towards the radial direction of the working chamber of the smoother.

2. CHARACTERISTICS OF THE 3-STEP SURFACE TREATMENT PROCESS

The research carried out at the Department of Production Engineering in Koszalin showed that the impact energy of the working charge composed of abrasive media in a rotary-cascade container smoothing machine in a steady state is variable in its axial cross-section [1,2]. The values and distributions of this energy can be determined by measuring the maximum values of the AE acoustic emission signal, as a result of which it is possible to develop energy maps in the axial section of the bowl (Fig. 1).

The knowledge of the locations and the size of the areas with a specific energy of action may be the basis for indicating them in order to conduct the treatment ensuring its greatest intensity or technological quality of the treated surface. In such a case, the spatial orientation of the workpieces should be appropriately enforced by the holder that implement the positioning movement in the radial and axial coordinate system of the smoothing machine [1]

The idea of a 3-stage smoothing process is based on three stages of surface treatment, carried out in a rotary-cascade container smoothing machine with a temporary orientation of the object by means of an active holder in specific places of the bowl, characterized by different energy levels and processing potential. These stages include (Figure 2):

1. Pre-treatment with abrasive media of the object mounted in the holder enabling additional rotational and vibrational movement in an orientation perpendicular to the direction of operation of the abrasive media, in order to intensively remove large surface irregularities resulting from previous machining operations and to unify the geometric structure of the surface.
2. Smoothing with abrasive media of an object mounted in a holder, with the surface orientation tangential to the direction of movement of the abrasive shapes, in order to remove surface irregularities from the previous treatment (machining in full material) leading to the expected low final surface roughness.
3. Finishing of the workpiece mounted in a holder, with the workpiece surface oriented in the direction normal to the direction of movement of the abrasive media, leading to the expected low final surface roughness.

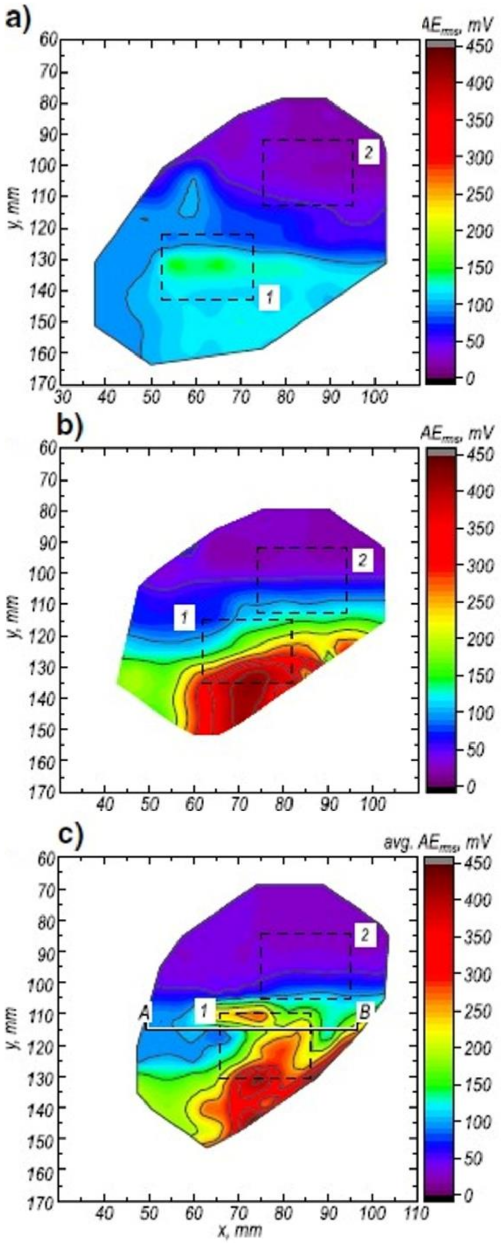


Fig. 1. Distribution of average values of acoustic emission signal energy (AE_{rms}) in the working bowl cross-section for different rotational speeds: a) 150 rpm, b) 300 rpm, c) 450 rpm [3]

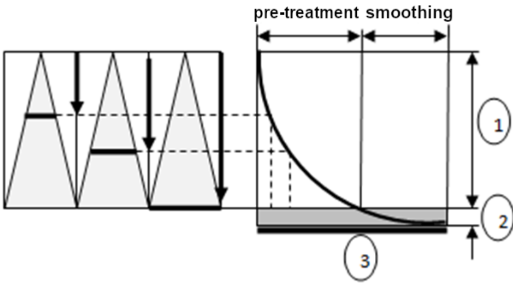


Fig. 2. Diagram of the process of shaping the geometric structure of the surface in the process of the 3-stage smoothing of the container in the object holder

The duration of the individual stages of treatment can be controlled by the intensity of the treatment, the type of working shapes and the expected roughness of the initial surface in these stages. It depends mainly on the type of processed material, its machining properties and weight.

The following steps may occur in the various steps of the 3-step smoothing process:

1. At the pre-treatment stage:
   - location of the workpiece in the zone of the highest energy level of the working load,
   - perpendicular orientation of the workpiece surface to the direction of action of abrasive fittings,
   - the use of abrasive media with the highest machinability ensuring the highest possible machining intensity,
   - application of high rotational speed rotor of the working chamber of the machine.
   - application of counter-rotating rotation of the workpiece
2. At the stage of finishing treatment:
   - the location of the workpiece in the zone of the average energy level of the working load,
   - tangential orientation of the workpiece surface to the direction of action of abrasive media,
   - application of a lower rotational speed of the machine,
   - the use of chemically active liquids supporting the treatment, especially activating the processes of etching and passivation of the surface, and facilitating its removal by abrasive media with micrograins.
3. At the polishing stage:
   - application of polishing media: porcelain, urea, metal fittings, glass fittings and nylon fittings,
   - the use of chemically active treatment aids, especially activating the processes of etching and passivation of the surface and making it easier
   - the location of the workpiece in the zone of low energy level of the working load.

3. EXPERIMENTAL STUDIES OF THE 3-STAGE SMOOTHING PROCESS

The aim of the research was to determine how the orientation of the workpiece in the working media in the radial direction of the container smoothing machine affects the efficiency of surface smoothing and the quality of the geometric structure of its surface. The tests were carried out on an EC6 rotary smoothing machine produced by the AVALON MACHINES sp. z o.o. (Fig. 3).

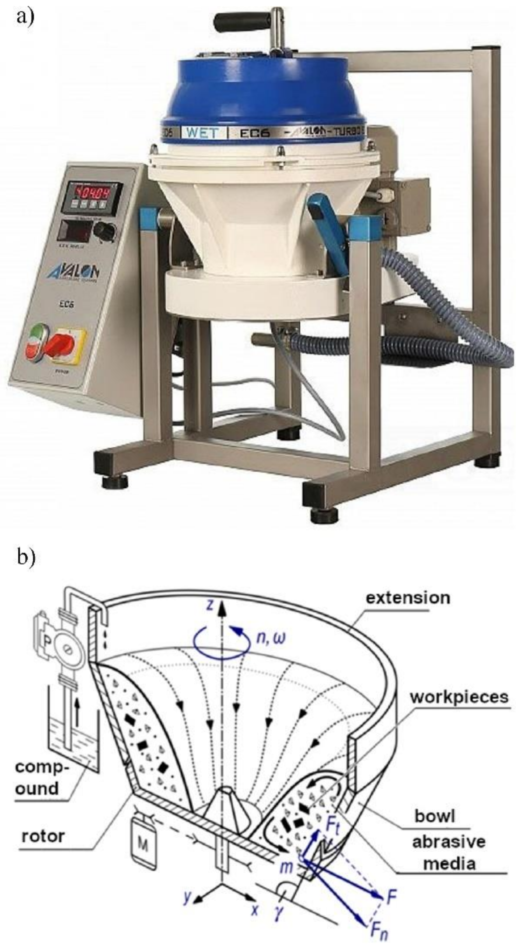


Fig. 3. Rotary and cascade container smoother EC6: a) general view, b) diagram of the working chamber

The EC6 smoothing machine dimensions: 525×486×702mm. It has a working chamber with a volume of 6 dcm3 and a diameter of 210mm. Charge weight: resin shapes 4 kg, ceramic shapes 5 kg, porcelain shapes 6.5 kg, stainless steel charge 18 kg. It is a device designed for mass processing of about 0.5 kg of objects at the same time. Enables the processes of deburring, edge rounding, cleaning, smoothing, matting, coarse and finishing grinding and polishing, with the use of ceramic, resin and porcelain fittings.

Plane-parallel objects with dimensions of 30x20x3mm, made of ANSI.304 stainless steel with the initial roughness parameters *Sa* = 2.52 µm and *Sdr* = 7.74%, were tested. Ceramic abrasive blocks GP10x10BD (designation acc. To AVALON), characterized by a high machining potential, were used as the working charge (Fig. 4).

Fig. 4. Ceramic abrasive fittings GP10x10 BD (inclined prism)

In order to give the object a rotary motion combined with a vibrating motion, an active object holder was used, which additionally allows the workpiece to be moved in the radial direction of the smoothing machine, holes leading the object holder (Fig. 5).

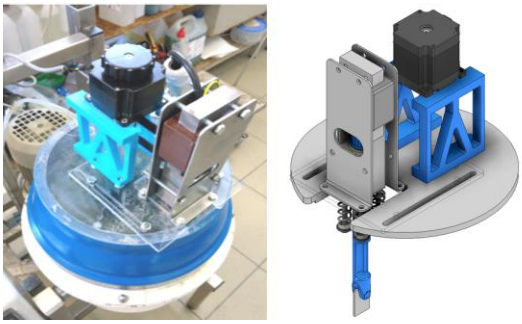


Fig. 5. Object holder: a) general view, b) handle mounted on the base based on the working chamber of the EC6 smoothing machine

The high-intensity machining variant was used, with the highest possible rotational speed of the smoothing rotor n = 450 rpm (Fig. 6), the vibration amplitude of the workpiece A = 1 mm and the vibration frequency f = 65Hz, the workpiece rotational speed, e.g. 5 rpm. The object was oriented in three zones of the work charge with different levels of kinetic energy at a given rotational speed of the smoothing rotor.

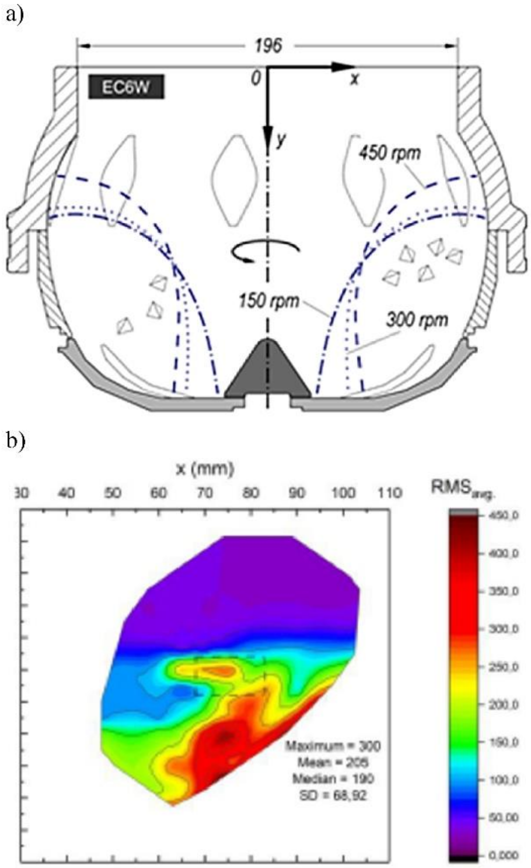


Fig. 6. Cross-sections of the work charge in the EC6 smoothing machine depending on the rotational speed a) and the energy distribution of the charge AE_{rms} at the rotational speed n = 300 rpm b) [3]

Based on the analysis of the kinetic energy distribution of the work charge in the cross-section to the direction of its rotational motion, the following positions of the workpiece for individual stages were adopted (Fig. 7).

1. Pre-treatment stage: R = 69 mm.
2. Smoothing treatment stage: R = 56.5 mm.
3. Finishing stage: R = 44 mm.

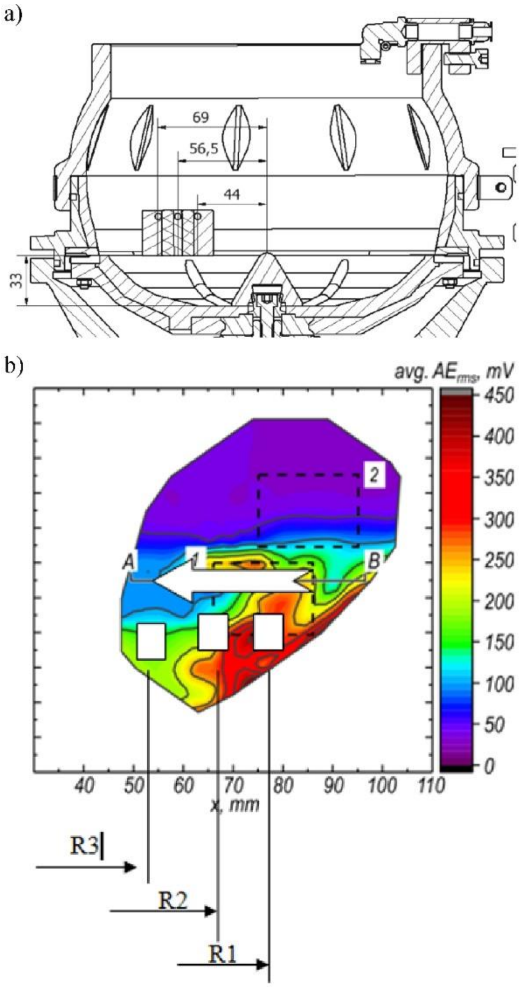


Fig. 7. The radial position of the measurement points for the individual processing steps a), the distribution of the average energy values of the AE_{rms} acoustic emission signal in the cross section of the work load for the rotational speed of the EC6 smoothing machine rotor (n = 450 rpm) b)

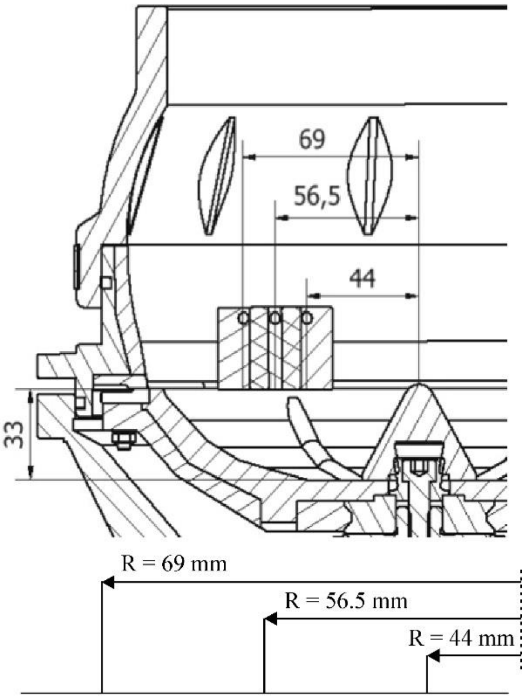
In the adopted test program, the following conditions for the machining process were adopted:

1. Pre-treatment step (R=69 mm), machining time t = 15 min
2. Smoothing treatment step (R=56.5 mm), (Sample after pre-treatment stage t=15 min), machining time t = 15 min
3. Finishing stage (R=44 mm), (Sample after pre-treatment stage t = 15 min and smoothing stage t = 15 min), machining time t = 15 min

Total machining time:

$$Stage\ 1 + Stage\ 2 + Stage\ 3 \ = \ 45\ min.$$

The test was repeated three times. The obtained results of roughness of the machined surfaces are measured by contact profilometer Hommel Tester T8000 with measuring sensor TKL 100, shown in the Fig. 8. Measuring accuracy was up to 0,2 µm.



Sa = 1.94 µm	Sa = 1.73 µm	Sa = 1.03 µm
I = 38.4%	I = 47.0%	I = 49.2%
Sdr = 6.34%	Sdr = 4.41%	Sdr = 4.20%
SPc = 4.19 pks/mm^2	SPc = 2.38 pks/mm^2	SPc = 1.07 pks/mm^2

Fig. 8. Parameters of the geometrical structure of the machined surfaces obtained in the subsequent stages of machining with the orientation of the workpieces in the zones of the working media with a decreasing value of kinetic energy

The results of these tests confirm that the periodic displacement of the workpiece towards the machine axis in the successive stages of machining has a positive effect on the progressive reduction of the surface roughness. Despite the use of relatively short times of these processing steps t = 15 min, the degree of surface development characterized by the Sdr parameter is significantly reduced, with a simultaneous significant smoothing of uneven peaks and reducing their number on the unit surface SPc. This way of organizing the smoothing process can be used to extend the possibilities of controlling the course of machining.

For comparison, a 1-stage treatment was carried out with the workpiece being placed in the area of the highest energy level of the work charge at the radius $R1$ = 69 mm. The same machining parameters were used: n = 450 rpm, *e.g.* = 5 rpm, A = 1mm. f = 65 Hz, t = 45 min. Under these conditions, the roughness of the treated surface was Sa = 1.63 µm, with a significantly greater degree of its development, Sdr = 4.63%. This proves that this machining process is relatively less efficient.

The smoothing efficiency of surfaces shaped in the tested variants of the machining process was calculated from the following relationship:

$$\Delta Sx = \frac{Sx(0)-Sx(45)}{Sx(0)} \cdot 100\% \,, \qquad (1)$$

where: ΔSx – relative difference of the SGP parameter, $Sx(0)$ – the initial value of the selected SGP parameter, $Sx(45)$ – the final value of the selected parameter.

With regard to the Sa and Sdr parameters, calculated efficiency indicators of the machining process are presented in the Tab. 1.

Tab. 1. Values of the parameter ΔSa and ΔSdr for the tested treatment methods

Machining method	Parameters of the surface texture	
	Δ *So*, %	Δ*Sdr*, %
Bulk machining	ΔSa=35.3%	ΔSdr=40.2%
3-step machining	ΔSa=59.1%	ΔSdr=45.8%

4. CONCLUSIONS FROM THE CONDUCTED RESEARCH

On the basis of the results obtained from the research and the analyzes carried out, it can be concluded that:

1. The proposed 3-stage processing process allows the use of different energy levels of the working media of the container smoothing machine by moving the workpiece in the radial direction of the container smoothing machine. It allows to control the course of the pre-treatment, smoothing and finishing intensity, both in terms of parameters and time of treatment.
2. Such a structure of the machining process also allows influencing the geometrical structure of the machined surfaces in the successive machining stages and, consequently, on the final quality.
3. The proposed organization and structure of the process allows for the creation of new surface treatment strategies.
4. The efficiency of described process is significantly higher comparison of the index values.
5. The presented example should be treated as exploratory research, showing new possibilities for the development of the surface smoothing process in the rotary-cascade smoothing machine.

References

1. Hashimoto Y. i In.:Fundamental investigation of gyro finishing experimental investigation of contact force between cylindrical workpiece and abrasive media under dry condition. Precision Engineering 67, 2021.
2. Sutowski P., Plichta J., Kałduński P.: Determining kinetic energy distribution of the working medium in a centrifugal disc finishing process- part 1: theoretical analis. The International Journal of Advanced Manufacturing Technology 2019.
3. Sutowski P., Plichta J., Kałduński P.: Determining kinetic energy distribution of the working medium in a centrifugal disc finishing process- part 2: experimental analysis with the use of acoustic emission signal. The International Journal of Advanced Manufacturing Technology 2019.
4. Plichta J., Juniewicz M.: Research on the influence of workpiece orientation during processing in disc centrifugal machine on the geometrical structure of its surface and processing efficiency. Journal of Mechanical and Energy Engineering, 2020.
5. Kopp M., Uhlmann E.: Potential of robot-guideg centrifugal disc finisher. Proceedings of the 1th Congress the German Academic Assosation for Production Technology. Dresden 2021.
6. Lachenmaier M. in.:I nfluence of different input parameters on the contact conditions determing the surface integrity of workpieces in unguided vibratory finishing process. CIRP vol.71,2018.
7. 54.Zenger F. i in.: Optimization of the stream finishing process for mechanical surface treatment by numerical and experimental process analisis. CIRP, vol.68/1, 2019.

Biographical notes

Mateusz Juniewicz received his M.Sc. degree in Mechanics and Machine design in 2017 at the Faculty of Mechanical Engineering of the Koszalin University of Technology. His diploma thesis entitled: "Modification of the rotary smoothing machine to vibration-stream treatment" was elaborated under the direction of Prof. Jarosław Plichta.

Jarosław Plichta received his M.Sc. degree in Mechanics and Machine Design and next Ph.D as well as D.Sc. degree and professor title in Machinery Construction and Operation, in 1976, 1981, 1997 and 2010, respectively. Since 2006 he was head of the Department of Production Engineering at the Koszalin University of Technology. His scientific interests focus on abrasive processes and tools, monitoring and diagnostics of machining processes as well as metrology. He has managing 4 national research projects, presenting results of his work at many international and national conferences, published more than 120 scientific papers in international and national journals, book chapters, as well as conference proceedings. He is also the author of 6 monographs, 4 academic textbooks and 11 national patents.