Vol. 2 2012

Development in Machining Technology

Scientific Research Reports

Edited by
Wojciech Zębala
Ildikó Maňková

Cracow University of Technology

This study aims to provide the recent advances in machining for modern manufacturing engineering, especially CNC machining, modern tools and machining of difficult-to-cut materials, optimization of machining processes, application of measurement techniques in manufacturing, modeling and computer simulation of cutting processes and physical phenomena.

ISBN 978-83-7242-655-0

DEVELOPMENT IN MACHINING TECHNOLOGY Scientific Research Reports Vol.2 2012

Editors: Wojciech Zębala, Ildikó Maňková

Project of cover: Łukasz Ślusarczyk, Grzegorz Struzikiewicz

Text arrangement: Grzegorz Struzikiewicz

All papers published in Scientific Research Reports issue had been reviewed and revised by Board of Reviewers

List of Reviewers:

Prof. Peter Demec, TU Kosice
Prof. Janos Kundrák, TU Miskolc
Prof. Gyula Varga, TU Miskolc
Prof. Imrich Lukovics, UTB Zlin
Prof. Czesław Niżankowski, TU Cracow

ISBN 978-83-7242-655-0

Druk i oprawę wykonano w Dziale Poligrafii Politechniki Krakowskiej
ul. Skarżyńskiego 1, 31-866 Kraków; tel. 12 628 37 29

Zam. 202/2012 Nakład 50 egz.

Table of Contents

Preface 5

Part 1. Machining of Difficult-To-Cut Materials **7**

Chapter 1.1. Investigation of hardened tool steel turning with CBN inserts – by Zębala W., Siwiec J., Cracow University of Technology 9

Chapter 1.2. Rates of used-up coolant and lubricant in hard machining – by Kundrák J., Molnar V., University of Miskolc 24

Chapter 1.3. The effect of the lengths of bore holes on the machining times in hard machining – by Kundrák J., Gyáni K., Deszpoth I., University of Miskolc 33

Chapter 1.4. Hard turning with rotational feed procedure – by Kundrák J., Gyáni K., Deszpoth I., Szabó S., University of Miskolc 42

Chapter 1.5. Modeling of polypropylene and polycarbonate grinding - artificial intelligence approach – by Samek D., Bilek O., Lukovics I., Tomas Bata University in Zlin 50

Chapter 1.6. Selected properties of the top layers of corrosion-resistant steel surfaces subjected to smoothing with new-generation flexible grinding discs – by Niżankowski Cz., Otko T., Cracow University of Technology 70

Part 2. CAD/CAE/CAM Techniques **81**

Chapter 2.1. Study of z-level finishing milling strategy – by Miko B., Obuda University in Budapest 83

Chapter 2.2. Some aspects of milling process planning when producing form surfaces – by Beňo, J., Stahovec J., Ižol P., Tomáš M., Technical University of Košice 91

Chapter 2.3. The influence of milling strategies on the productivity and accuracy when machining free form surface – by Kandráč L., Maňková I., Vrabel M., Greškovič F., Technical University of Košice 104

Chapter 2.4. Mould Design with CATIA V5 System- Pressure Casting – by Rokyta L., Lukovics I., Bilek O., Tomas Bata University in Zlin 114

Part 3. Non Traditional Machining **121**

Chapter 3.1. Fractal analysis of the structure of geometrical surface after EDM – by Struzikiewicz G., Magdziarczyk W., Cracow University of Technology 123

Chapter 3.2. Correlation between WEDM conditions and shape errors – by Ślusarczyk Ł., Cracow University of Technology 134

Chapter 3.3. Laser cutting of complex profile in low carbon and stainless steel parts – by Zębala W., Matras A., Kowalczyk R., Cracow University of Technology 147

PREFACE

Machining is one of the most popular technique to change shape and dimensions of the objects. Machining operations can be applied to work metallic and non-metallic materials such as ceramics, composites, polymers, wood.

Cutting tools have been used since ancient times to remove excess material from forgings and castings. Nowadays, metal cutting became one of the primary manufacturing processes for finishing operations. In the last few years we have observed a rapid development in automation of manufacturing processes, especially in automatic control systems. Progress in cutting stimulates a significant increase in the metal removal rate and achieving high accuracy in terms of dimensions and shape of machine parts. New materials, which play the key role here, are used to produce cutting tools.

To meet today's high demands concerning accuracy and efficiency of the manufacturing process of machine parts, it is necessary to use computer methods for designing of technological processes.

This study aims to provide the recent advances in machining for modern manufacturing engineering, especially CNC machining, modern tools and machining of difficult-to-cut materials, optimization of machining processes, application of measurement techniques in manufacturing, modeling and computer simulation of cutting processes and physical phenomena.

Wojciech Zębala

PART 3

Non Traditional Machining

Chapter 3.2

CORRELATION BETWEEN WEDM CONDITIONS AND SHAPE ERRORS

Ślusarczyk Ł.
Cracow University of Technology, Poland

Abstract: *The article describes the stages of design and implementation of objects on the electroerosion wire cutter BP-95d, next conducted analysis of the influence of WEDM conditions processing on shape errors of objects carried out. Practical part consisted in cutting three cylinders out about 30 mm diameter. Stainless steel metal sheet was processed of the 15.43 mm thickness. Cylinders were cut with the same parameters. The difference was, that in two first attempts, deionized water was provided to the processing zone from the bottom and top, however in the third case – only from the top. Additionally one hole formed in the material after cutting the cylinder – hole 2, was machined with finishing pass. The measurement was carried out in three plains: 1, 7 and 15 mm, for every element. Analyzing received results, roundness deviation of the outline roundness was determined. Talyround 365 device was used to measure the roundness of cylinders and holes.*

Keywords*: Machining, WEDM, CNC*

1. Introduction

Development of industry requires the increase of accuracy of produced objects. For providing the reliability of produced devices, it is necessary to increase the accuracy of shapes and dimensions. Additional it requires reducing the roughness of produced devices parts. EDM processing (ang. Electrical Discharge Machining) has been applied in the industry for about sixty years, as the way of shaping objects conducting electric current, by removing extra material, as a result of electric discharges between two electrodes in the liquid dielectric center. At first EDM was applied to carry out all types of cavities and holes. At the end of sixties the 20th century, appears a new kinematic variety, electroerosion cutting wire (ang. Wire Electrical Discharge Machining)[3,4,5].

2. Wire electrical discharge machine BP-95d

Wire cutter BP-95d is a 2-axis device and is used to cut details in the materials conducting electric current (copper, aluminum, steel, sinters) by electro-spark method[7]. Copper wire is a working electrode about the diameter 0.25 mm, moving vertically to the table in slideways. Electric impulses are generated through iso-frequency transistor generator. The wire cutter is used to perform core cutters, tools, forms and many other details. It was adapted to the cooperation with computer and CAD/CAM MegaCAD program. The cut takes places along with earlier planned motion track in deionize water surrounding provided to the zone processing with spray method. Local keyboard allows the operator to enter data according to the internal programming system of driving track. Equidistant function accessible in the program CAD/CAM MegaCAD solves the problem of correction cutting track associated with the width of working crack [6].

Fig. 1. Picture of the workstation consisting of electroerosion wire cutter BP – 95d and transistor pulse generator

3. Practical part – cutting elements

In frames of the work, elements prepared earlier in the MegaCAD application were cut out. Practical part consisted in cutting three cylinders out about 30 mm diameter. Cylinders were cut with the same parameters of machining, described in Table 1. The difference was, that in two first attempts, deionized water was provided to the zone processing from the bottom and top, however in the third case – only from the top. Additionally one hole formed in the material after cutting the cylinder – hole 2, was machined with finishing pass. Stainless steel metal had 15.43 mm thickness.

Table 1. Parameters of driving during cutting cylinders out

Material Type	Stainless steel
Material Height [mm]	15.43
Diameter of the cylinder [mm]	30
Interpolation Step [mm]	0.1
Wire Speed [mm/s]	0.04
EQ [mm]	0.14
Speed of the cylinder cutting [mm/s]	0.017
Spark out speed [mm/s]	0.17
Time of cutting [s]	5700

Fig. 2 presents working board of the electroerosion wire cutter along with mounted machined material, from which cylinders were cut.

Fig. 2. Way of mounting processed material, from which cylinders were cut

4. Recording of electricity and tension proceedings

The value of driving electricity, for every cutting cylinder operation amounted 72 A, however the voltage value amounted 300 V. During the process of cutting cylinders the courses of tension and intensity were recorded with oscilloscope KIKUSUI COR 5541U. Times of impulses and breaks obtained from the generator were similar for all cases and amounted appropriately: time of impulse about 28 μs, however break between impulses about 346 μs. Fig. 3, 4 and 5 presents examples of impulses.

Fig. 3. Example of impulse approximately amounting 28 28 μ s recorded on the oscilloscope KIKUSUI COR 5541U during cutting cylinders

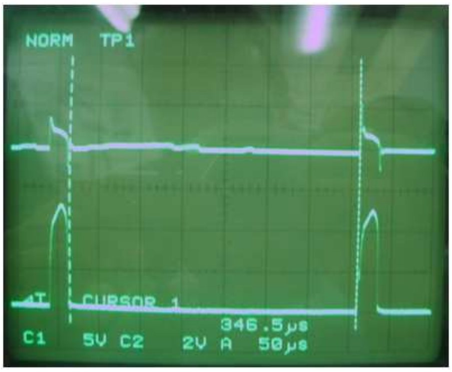


Fig. 4. Example of break between impulse approximately amounting 346.5 μ s recorded on the oscilloscope KIKUSUI COR 5541U during cutting cylinders

During processing some empty impulses were observed (Fig. 5).

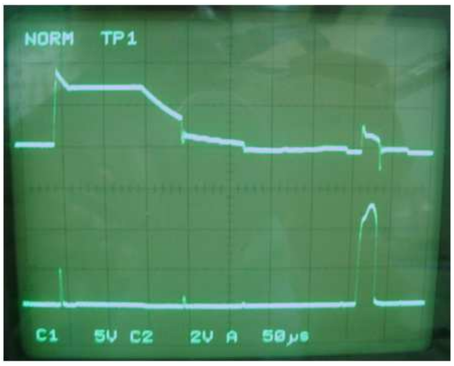


Fig. 5. Photography of the empty impulse – lack of puncture

Next stage of the work was verification of roundness and rollerness previously cute cylinders and holes, Fig. 6, using Talyrond 365 of the Taylor Hobson Company.

Fig. 6. Cylinders and holes cut out by the electroerosion wire cutter

In Fig. 7 three marked plains at height 1, 7 and 15 mm, on which roundness measurements were conducted are presented. Similarly as for cylinders, the roundness holes measurements were performed in three plains at height 1, 7 and 15 mm.

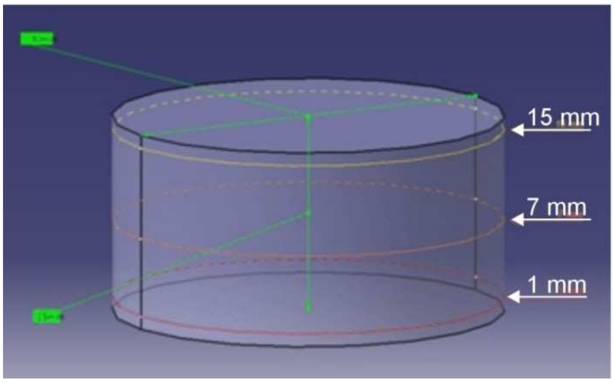


Fig. 7. Outlines roundness strategy measurements in three planes of the cylinder

The analysis of measurement results and their visualization helps to detect serious defects in shape. Metrological measurements are only one elements of the quality check of finished product. Talyrond 365, Fig. 8 is a modular measuring tool with high accuracy and reliability. The device has an automatic calibration and is one from the first in the industry instruments of the medium scope for examining the roundness [22]. Patented three – points, kinematic supporting system was designed so that it could cooperate with other instruments for examining the roundness. During centering, spindle turns in the constant way, what was called state of the dynamic equilibrium. Lack of zero point means that elements can be centered and leveled in any place on the countertop. Column and Talyrond 365 arm are able to make measurement of the object extentricity and parts apart from the scale.

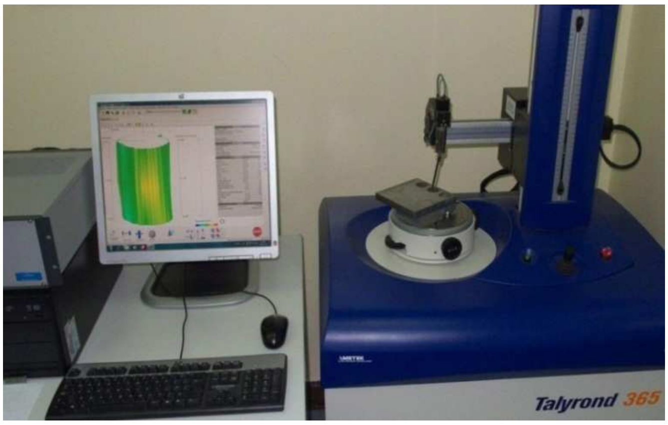


Fig. 8. Talyrond 365 of the Taylor Hobson company

In Fig. 9 a rotational table is presented with cylinders placed on it along with the measuring spire during the measurement.

Fig. 9. Close-up the rotational table along with cylinders during measurement

Coordinate-measuring technique used in measuring machines for the evaluation of outlines roundness consists in setting coordinate points (x_i, y_i) forming the real outline, set by coordinate-measuring system (x, y) of the measuring machine (Fig. 10).

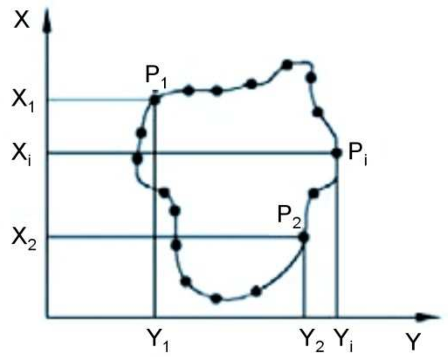


Fig. 10. Principle of the outlines roundness coordinate measurement [1]

Determined by the measuring system points of the roundness outline enable to present in the plane outline of measured system, and based on mathematical relations allow for outlining the combined circle. Four combined circles are distinguished (Fig. 11):

a) MZCI – circles of the smallest zone
b) LSCI – circle of the smallest squares
c) MCCI – the smallest described circle
d) MICI – the biggest recorded circle [1,2]

Reference circle is used to determine the deviation of roundness. RONt parameter which was defined as the sum of largest positive local roundness deviation (RONp) and absolute values of the largest negative local roundness deviation established for any circle of the reference (RONv).

Next stage of the work was to analyze measurement results of the cylinder 1, 2 and 3 roundness and roundness of the holes No. 1, 2 and 3 by means of Taylorond 365.

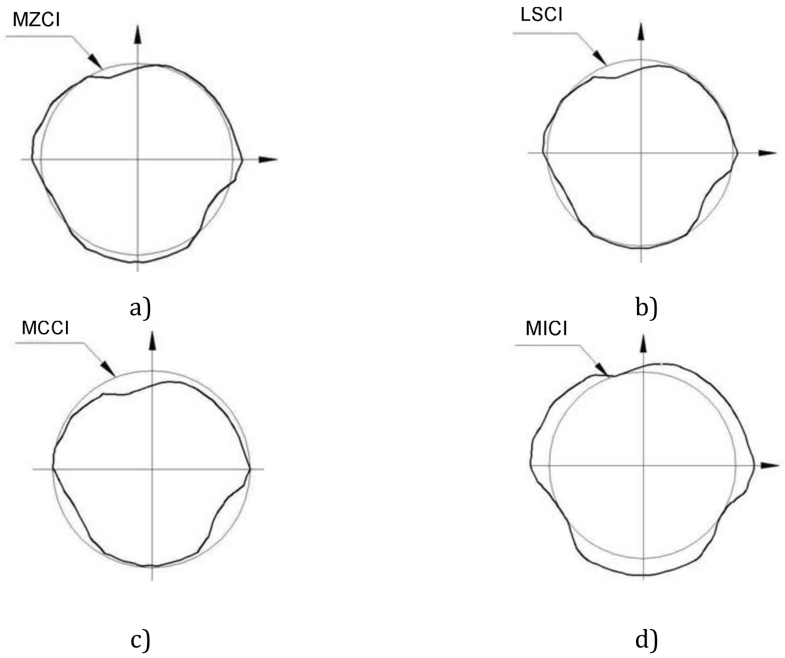


Fig. 11. Associated circles established based on the coordinate measurement: a) circles of the minimal zone; b) smallest squares; c) smallest described; d) biggest recorded [10]

Fig. 12, 13 and 14 present the analysis of examples of measurements results of the cylinder roundness no. 2.

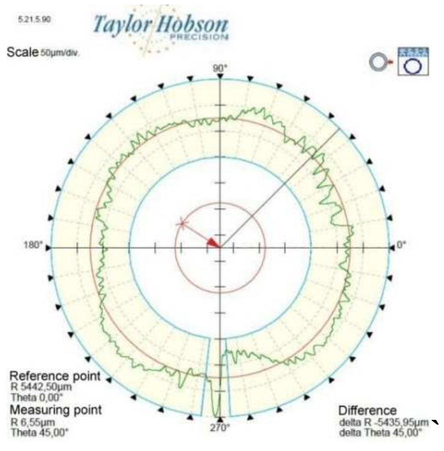


Fig. 12. Polar graphs and outline of roundness deviations of the cylinder at height: 1 [mm]

Fig. 13. Polar graphs and outline of roundness deviations of the cylinder at height: 7 [mm]

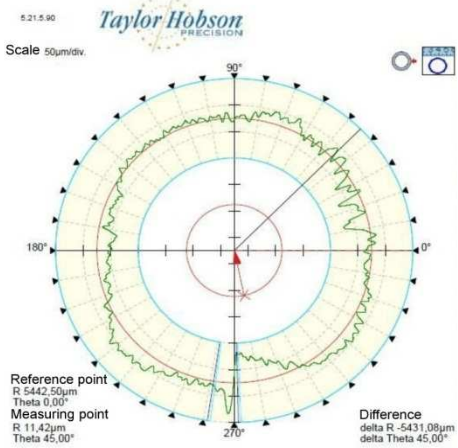


Fig. 14. Polar graphs and outline of roundness deviations of the cylinder at height: 15 [mm]

The roundness deviations for the cylinders no. 1 and 2 were the same, because of the processing conditions, whereas for the cylinder no. 3 were different.

Based on conducted measurements of the cylinders roundness, a table of results (Table 2) and graphs parameters RONp, RONv, RONt and Run-Out were created.

Table 2. Roundness deviations of cylinders in three planes

		Roundness deviations							
		RONp [μm]		**RONv [μm]**		**RONt [μm]**		**Run-Out [μm]**	
		Cyl.1-2	Cyl.3	Cyl.1-2	Cyl.3	Cyl.1-2	Cyl.3	Cyl.1-2	Cyl.3
Plane	**1 [mm]**	73.39	89.49	54.59	43.24	127.98	132.73	157.48	183.66
	7 [mm]	59.97	67.75	56.37	63.84	116.36	131.59	115.74	130.72
	15 [mm]	58.19	50.03	58.12	63.77	116.31	113.81	116.43	116.23

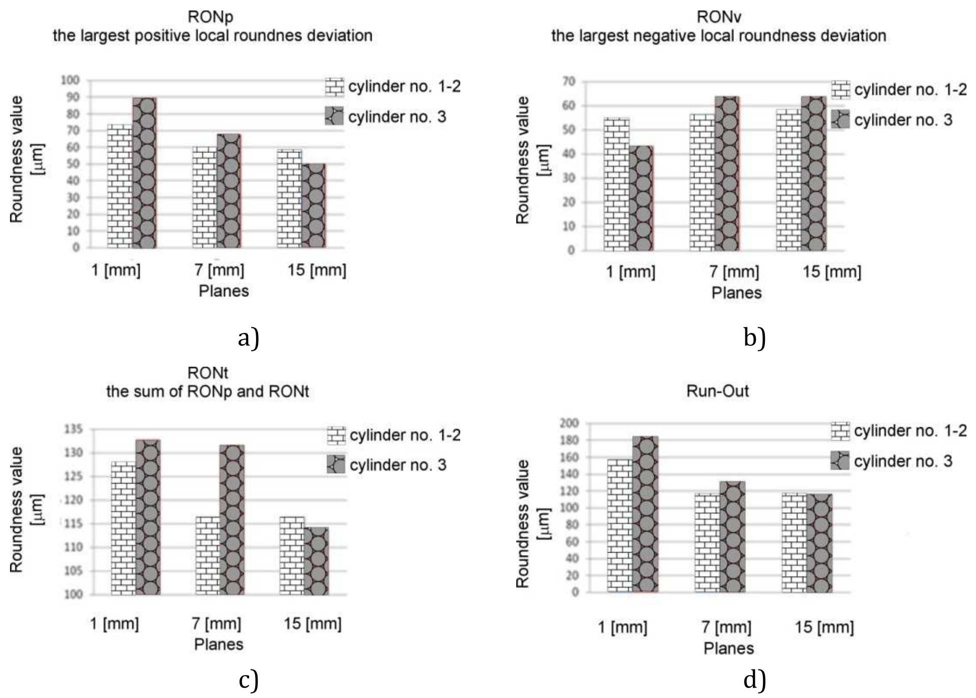
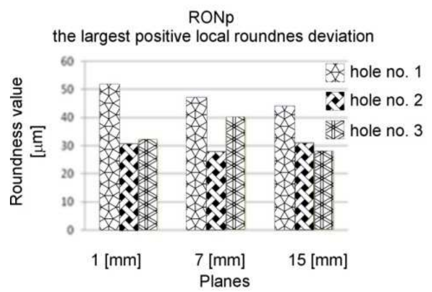


Fig. **15.** Roundness deviations of cylinders in three planes:
a) **RONp, b) RONv, c) RONt, d) Run-Out**

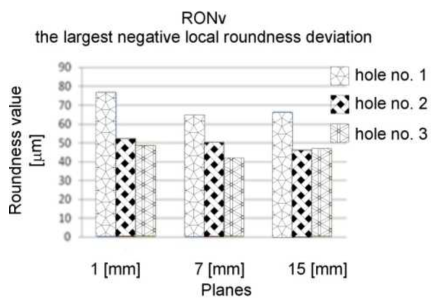
Based on conducted measurements research of the holes roundness 1, 2 and 3 a table of results (Table 3) and graphs parameters RONp, RONv, RONt and Run-Out were created.

Table 3. Roundness deviations of hole no. 1, 2 and 3 in three planes

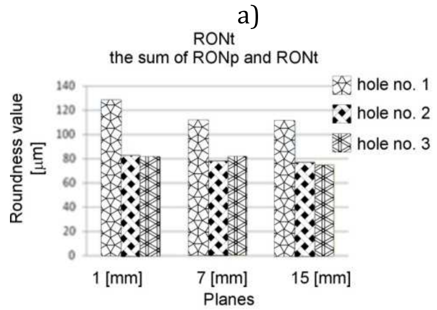
			Plane		
		hole no.	**1 mm**	**7 mm**	**15 mm**
Roundness deviations	**RONp [µm]**	hole 1	51.69	47.22	44.72
		hole 2	30.64	27.96	31.12
		hole 3	32.20	39.94	27.91
	RONv [µm]	hole 1	77.05	64.67	66.52
		hole 2	52.27	50.24	46.00
		hole 3	48.88	41.73	46.89
	RONt [µm]	hole 1	128.75	111.89	111.23
		hole 2	82.91	78.19	77.12
		hole 3	81.07	81.67	74.80
	Run-Out [µm]	hole 1	175.11	159.06	109.92
		hole 2	168.09	130.39	94.91
		hole 3	133.27	107.01	80.96



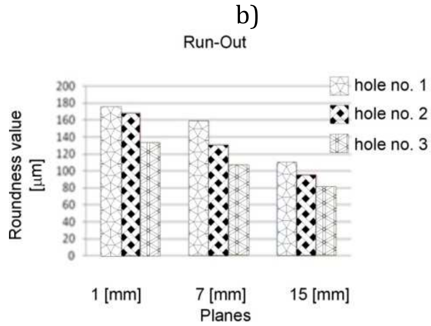
a)



b)



c)



d)

Fig. 16. Roundness deviations of holes in three planes:
RONp, b) RONv, c) RONt, d) Run-Out

5. Conclusion

Cylinders no. 1, 2 and 3 were cut with the same conditions of machining. The cylinders no. 1 and 2 were made under the same conditions, the deionized water was provided to the processing zone from the bottom and top. The cylinder no. 3 was made, when the deionized water was provided to the processing zone only from the top. The analysis of measurement results shows, that the roundness values for the cylinders no. 1 and 2 were the same. In case of cylinder 3 better parameters were obtained.

Comparing results for the hole 1 (without finishing pass) and hole 2 (after finishing pass) as well as hole 3 (closed bottom nozzle), it must be stated that smaller roundness deviations were obtained for the hole 2 and 3 relative to the hole 1. In case of the hole 2 smaller roundness deviations may result from the additionally finishing pass. In case of the hole 3 smaller roundness deviations may result from the fact that smaller amount of water provided to the zone processing improves the effectiveness of WEDM. Comparing the roundness deviations between the hole 2 and 3 it can be said that the best results are obtained in the case of the hole 2 when the additionally finishing pass was used.

In case of cylinders it is recommended to use in the process as small quantity of deionized water as possible, while in case of holes machining, the additionally finishing pass gives the best results.

References

[1] ADAMCZAK S. (1998) *Odniesieniowe metody pomiaru zarysów okrągłości części maszyn.* Wydawnictwo Politechniki Świętokrzyskiej. Kielce.

[2] ADAMCZAK S. (2008) *Pomiary geometryczne powierzchni. Zarysy kształtu falistości i chropowatości.* Wydawnictwo Naukowo – Techniczne. Warszawa.

[3] DĄBROWSKI L., MARCINIAK M., NOWICKI B. *Obróbka skrawaniem ścierna i erozyjna.* Oficyna Wydawnicza Politechniki Warszawskiej. Warszawa.

[4] MIERNIKIEWICZ A. *Doświadczalno-teoretyczne podstawy obróbki elektroerozyjnej (EDM)*. Politechnika Krakowska, Seria Mechanika. Monografia 274. Kraków.

[5] STÓS J., SZADKOWSKI J. (1999) *Prace instytutu obróbki skrawaniem Monografia*, Pracownia Reprografii i Wydawnictwo IOS. Kraków

[6] http://www.megacad.pl/

[7] http://www.zapbp.com.pl/