ANNALS of the ORADEA UNIVERSITY.
Fascicle of Management and Technological Engineering, Volume VII (XVII), 2008

RESEARCH OF OPTIMAL PARAMETERS OF MACHINING BIG HYDRAULIC CYLINDERS FROM THE ASPECT OF QUALITY

Abaz Manđuka[1], Predrag Dašić[2], Radoš Pantić[2]
[1] BNT - TMH, Novi Travnik, Bosnia and Herzegovina, bnt-tmh@bih.net.ba
[2] High Technical Mechanical School, Trstenik, Serbia, dasicp@yahoo.com

Key words: *hydraulic cylinder, machining, cutting tool, quality of machining*

Summary: Realization of high efficiency in industrial production from area of oil fluidics according to demands of modern society conditions development and application of specific technologies and technology processes. On order to carry out a good project of manufacturing hydraulic cylinders whose dimensions are Ø630x8520mm the factory from Trstenik, Serbia, called "PPT-Cilindri" has used not only its own research and development resources, knowledge of manufacturing the oil and hydraulic cylinders, but it has also cooperated closely with the factory from Novi Travnik, Bosnia and Herzegovina, called BNT-TMH. The paper shows the methodology of the research work done on machining parameters obtained during the technology of deep boring. The machining parameters have been applied to the manufacturing of the subassembly of hydraulic cylinder at the numerical systems at the factory BNT-TMH, Novi Travnik, Bosnia and Herzegovina.

1 INTRODUCTION

The quality of machined surface and geometric accuracy has a prime influence on the functional characteristics and reliability of all components and devices in a hydraulic system. Hydraulic cylinders are most often the actuators of hydraulic installation and system. They operate by translation or rotary motion of the piston, i.e. piston rod, in the cylinder while oil pressure acts as working fluid. Due translation, at the contacting surfaces of tribo-couple consisting of cylinder and piston (sealing set), there are some tribology processes whose intensity is influenced by the material of tribo-couple, the speed of motion, working fluid and by the quality and geometrical accuracy of the surface machined. Besides, the level of obtained tightness of tribo-couple results in energetic loss and pressure loss of working fluid, which decreases the reliability and efficiency of these devices. Since the devices of high pressure are in question, the quality of the surface and geometric accuracy of the cylinder are the parameters having a dominant influence on reliability and efficiency of these devices. To achieve the optimal parameters of the quality and accuracy of machining the hydraulic cylinders makes these operations and machining systems specific and complex, especially if the devices being machined are heavy.
In order to machine the hydraulic cylinders (Ø630H9x8520) during the technology of expansion, we have done the research to determine the optimal parameters and reliability of machining the cylinder subassembly. The analysis of machining process, the determination of optimal parameters and their influence have been done by experimental and analytical multi-factor method [1,4,16,17,20]. Since the machining process under realistic conditions of researching the optimal parameters is complex, only experimental and analytical methods provide proper description and optimisation of the cylinder and working processes in it [6,8-12,14-19].

2 RESEARCH SUBJECT AND RELEVANT ELEMENTS OF MACHINING PROCESS AND SYSTEM

In order to research the machining process during the technology of expansion we have chosen the function of roughness quality of machined surface *(R_a)* as a relevant parameter for the finish machining operation and for geometric accuracy of the subassembly of hydraulic cylinder. The vector coordinates of "entry" R_a have been chosen in order to define the values of entries (parameters) and to research the influences of these values on chosen state function:

$$R_a = f(v, s, \delta, r) \quad (1)$$

where:

v – cutting speed [m/min],
s – speed of secondary motion [mm/o],
δ – cutting debth [mm] and
r - radius of the roundness of cutting tool [mm].

2.1 ELEMENTS OF MACHINING SYSTEM

The relevant parameters of the elements of machining system are shown in Table 1 and in Figures 1 and 2.

Table 1: *Elements of machining system*

Elements	Parameters
Machine: WHB-85	Power EM: P=85 KW; max. length of machining $l \le$ 10.000mm; max. diameter of external machining: $d \le$ 850 mm; internal scraping $D \le$ 650 mm; machining type: external and internal scraping, external and internal honing in horizontal plane; type of driving the secondary motion: mechanical and hydraulic (continuous)
Tool: Special cutting head	Dimensions: Ø540 x 500 mm Guides: 2 x hard metal Guides: 4 x 50 x 350 mm Textolite Cutting tool: cassette and cutting plate CNMM1906xxEL, GC 4025
Attachment:	Tool carrier: Ø 300 x 18.000 mm Chuck: Ø 1600/6 Supports – immovable 2x
Sample:	Pipe Ø 722/600 x 2300, J – 55 (Č1212), R_m=450 N/mm^2 (S355J2G3), NFEN 10025 C 0,22; Si 0,55; Mn 1,60, P 0,04; S 0,04
Measuring tool:	Micrometer for openings, SUBITO Pertometer Talysur Φ5–M Taylor H
Cooling agent and lubricator:	Cutting oil, Q_{max} 150 l/min, P_{max} $30 \cdot 10^5$ Pa

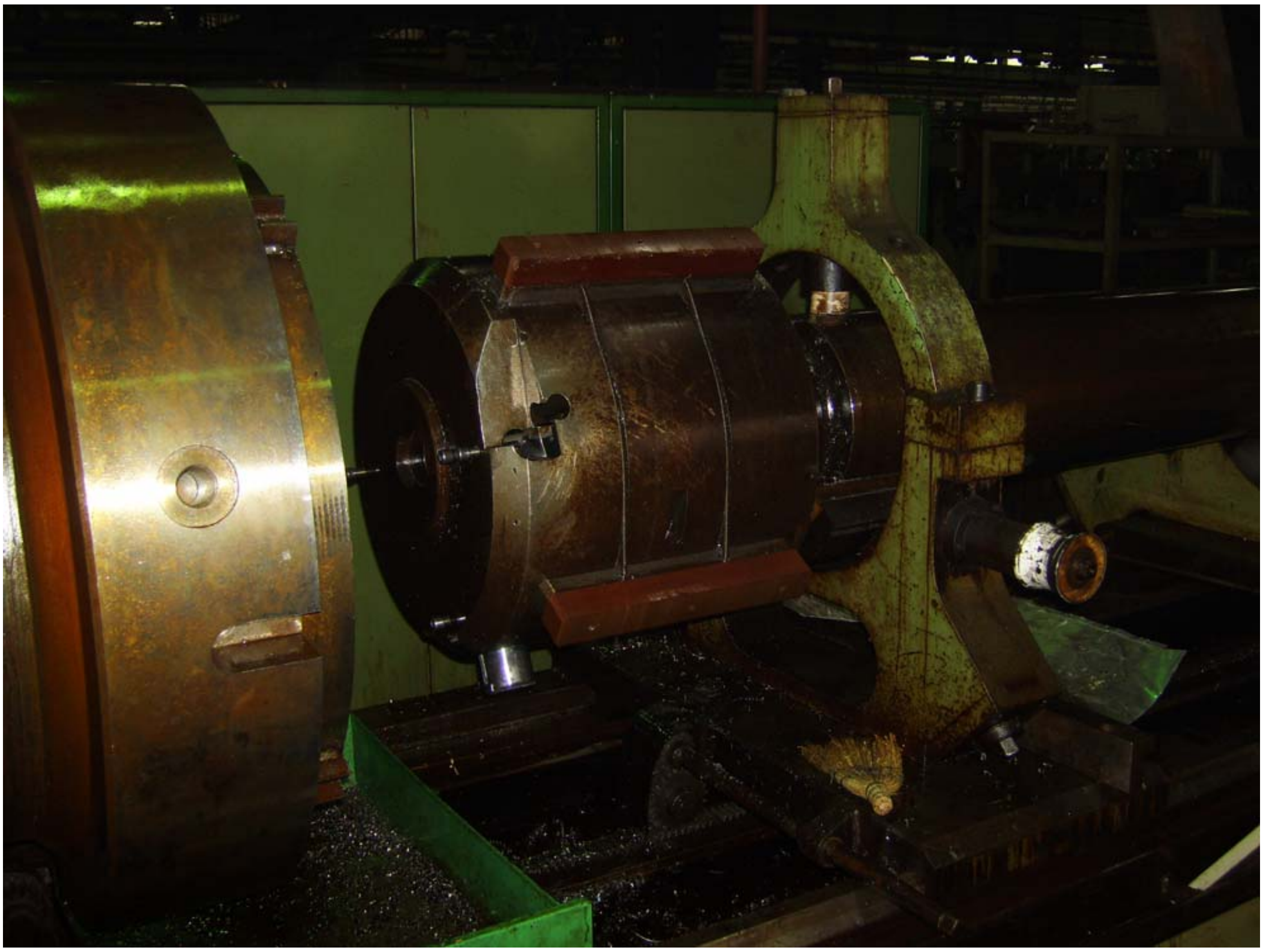


Figure 1: *Machine VHB – 85 and cutting head*

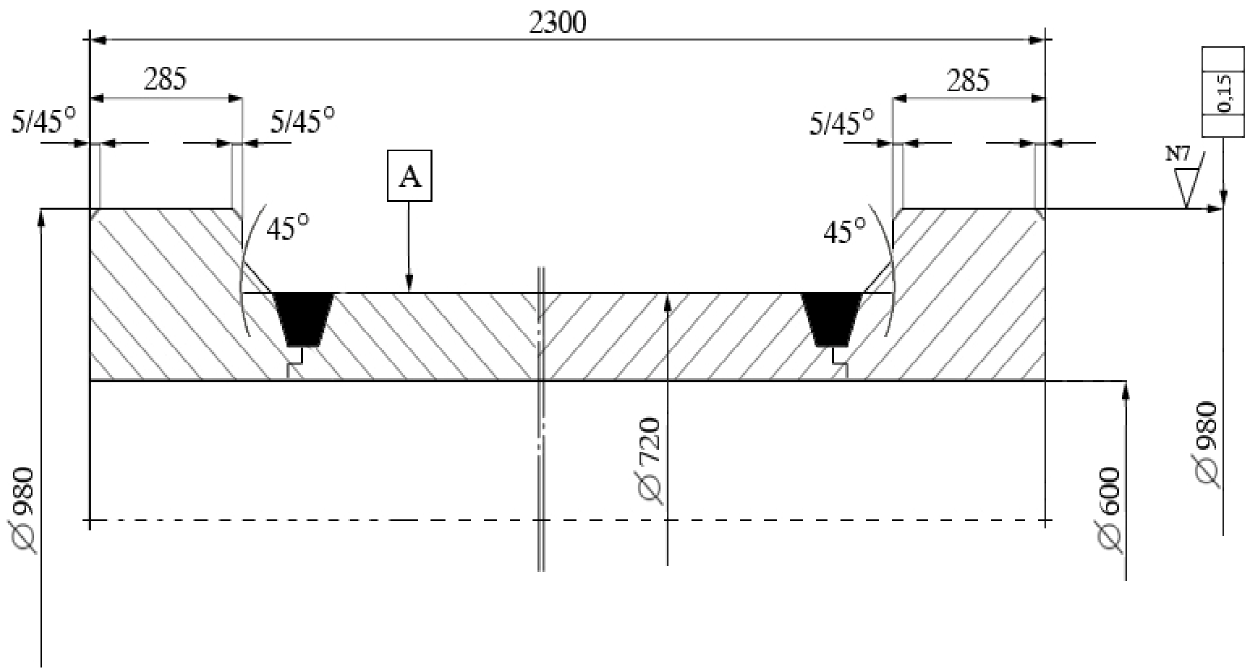


Figure 2: *Sample*

2.2 CODING THE VARIABLES OF THE STATE FUNCTION AND FORMING THE PLAN MATRIX OF THE PROCESS

The analysis of the process in natural coordinates (1) is hardly possible and applicable. Thus, all the variables are coded with x_i at three levels: mean (0), upper (+1), and lower (-1). Determination of mean level (0) is based on preliminary testing or on reference data, experience and recommendation. Upper (+1) and lower levels (-1), are determined on the basis of adopted widths of variation intervals provided that they are within applicable and allowable tolerance. Most often the values are preliminary checked by experiments and verified under realistic conditions. If the process with a large number of variables (factors) is analysed it is efficient to apply orthogonal plans of the first and higher order [1,2,4,5,7,13,16,17] formed by Plecent-Berman matrix. Acquired experience and knowledge show that these plans are the most reliable and efficient in the research of multi-dimensional processes with a larger number of chosen coordinates of entry vectors *(x)* and *Y* being the results of the process or system. During testing we have also measured some mean values of roughness parameters R_a [μm] depending on cutting speed *V* [m/min], pitch *s* [mm/o], cutting debth δ [mm] and roundness radius of tool tip *r* [mm]. The testing has been done under operating conditions at the factory BM-TMH – Novi Travnik. The mean values of roughness parameter R_a [μm] depending on *v*, *s*, δ and *r* according to four-factor plan of the experiment are shown in plan matrix (Table 2).

Table 2: *Plan matrix of four-factor experiment and measured values of mean arithmetic deviation of profile R_a [μm]*

No.	Coded values					Natural values				Measured values	
	x_o	x_1	x_2	x_3	x_4	v	s	δ	r	R_a	$\ln R_a$
1.	1	1	1	1	1	66,2	0,4	3	1,2	14,9	2,70136
2.	1	1	1	1	-1	66,2	0,4	3	0,8	18,3	2,90690
3.	1	1	-1	-1	1	66,2	0,3	2	1,2	9,5	2,25129
4.	1	1	-1	-1	-1	66,2	0,3	2	0,8	16,6	2,80940
5.	1	-1	1	-1	1	48	0,4	2	1,2	15,7	2,75366
6.	1	-1	1	-1	-1	48	0,4	2	0,8	20,1	3,00072
7.	1	-1	-1	1	1	48	0,3	3	1,2	13,3	2,58776
8.	1	-1	-1	1	-1	48	0,3	3	0,8	16,5	2,80336
9.	0	0	0	0	0	56	0,35	2,45	1	14,8	2,69463
10.	0	0	0	0	0	56	0,35	2,45	1	15,1	2,71470

The matrix formed in Table 2 provides:

- optimal arrangement of measuring points,
- minimal number of measuring points,
- maximal information on the process,
- minimal dispersion of measuring results,
- efficient and reliable analysis of the process.

3 MATHEMATICAL ANALYSES OF EXPERIMENTAL RESULTS

Mathematical processing of experimental results has been done by the methodology and software package CoREMED (***C****hoice* ***o****f* ***R****egression* ***E****quation of* ***M****ultifactor* ***E****xperiment* ***D****esign with and without Repeating*) [3].

There are four different regression equations for arithmetic mean of the profile $R_a=f(v,s,\delta,r)$. Both on the basis of calculated parameters of regression b_0 and b_i and on the basis of difference between determination coefficients (R^2) for each newly included regression equation we can calculate, according to the methodology presented in papers [2,4,7,13], the percentage of all regression parameters B_i in [%] (Table 3). Figure 4 shows relative percentage of each factor influencing the value of variable $R_a=f(v,s,\delta,r)$.
On the basis of calculated values of free element of polynomial b_o and line effects of factor b_i (i=1,2,3,4), the mathematical model with line effects of factor coded for mean arithmetic deviation of profile R_a is:

$$y = 2{,}72238 - 0{,}0596 \cdot x_1 + 0{,}1139 \cdot x_2 + 0{,}0230 \cdot x_3 - 0{,}1533 \cdot x_4 \qquad (2)$$

By means of equation (2) and data presented in Table 2 we can determine the free element of regression equations:

$$Q = \exp(b_o + \sum_{i=1}^{4} b_i \cdot a_i) = \exp(b_0 + b_1 \cdot a_1 + b_2 \cdot a_2 + b_3 \cdot a_3) = 139{,}5534 \qquad (3)$$

The parameters of decoded model with line effects q_i (i=1, 2, 3, 4) are based on the following equations:

$$q_1 = A_1 \cdot b_1 = -0{,}3706 \qquad (4)$$

$$q_2 = A_2 \cdot b_2 = 0{,}7915 \qquad (5)$$

$$q_3 = A_3 \cdot b_3 = 0{,}1136 \qquad (6)$$

$$q_4 = A_4 \cdot b_4 = -0{,}7561 \qquad (7)$$

where:

$$A_i = \frac{2}{\ln \frac{f_{imax}}{f_{imin}}}$$

$$a_i = 1 - A_i \cdot \ln f_{imax}$$

The regression equation in natural coordinates without interaction, i.e. the mathematical dependence of mean arithmetic deviation of profile R_a, can be expressed like this:

$$\boxed{R_a = 139{,}5534 \cdot \frac{s^{0{,}7915} \cdot \delta^{0{,}1136}}{v^{0{,}3706} \cdot r^{0{,}7561}}} \qquad (8)$$

The correlation coefficient for chosen regression equation without interaction is as follows:

$$R = 0{,}94865 \qquad (9)$$

4 SELECTION AND APPLICATION OF STANDARD MACHINING REGIMES

Selection of standard cutting regimes for machining the working piece (Figure 4) has been based on experimental results of roughness parameters R_a from plan matrix (Table 2) and on obtained functional dependence $R_a=Ra(v,s,\delta,r)$ according to equation (8) in allowable tolerance of machining regimes for machining system being researched.

Table 3: *Ranking and selection of factors influencing the function of arithmetic mean of the profile $R_a=f(v,s,\delta,r)$*

No.	Number of parameters according to their relevance	Regression parameters b_0, b_i	Determination coefficients (R^2) for the ranked regression equation	Percentage of regression parameters B_i, [%]
1.	-	b_0 = 2,7224	-	-
2.	3.	b_1 = -0,0596	0,86987	7,715
3.	2.	b_2 = 0,1139	0,79272	28,184
4.	4.	b_3 = 0,0230	0,89994	3,007
7.	1.	b_4 = -0,1533	0,51088	51,088
8.	-	remainer of variation	-	10,006

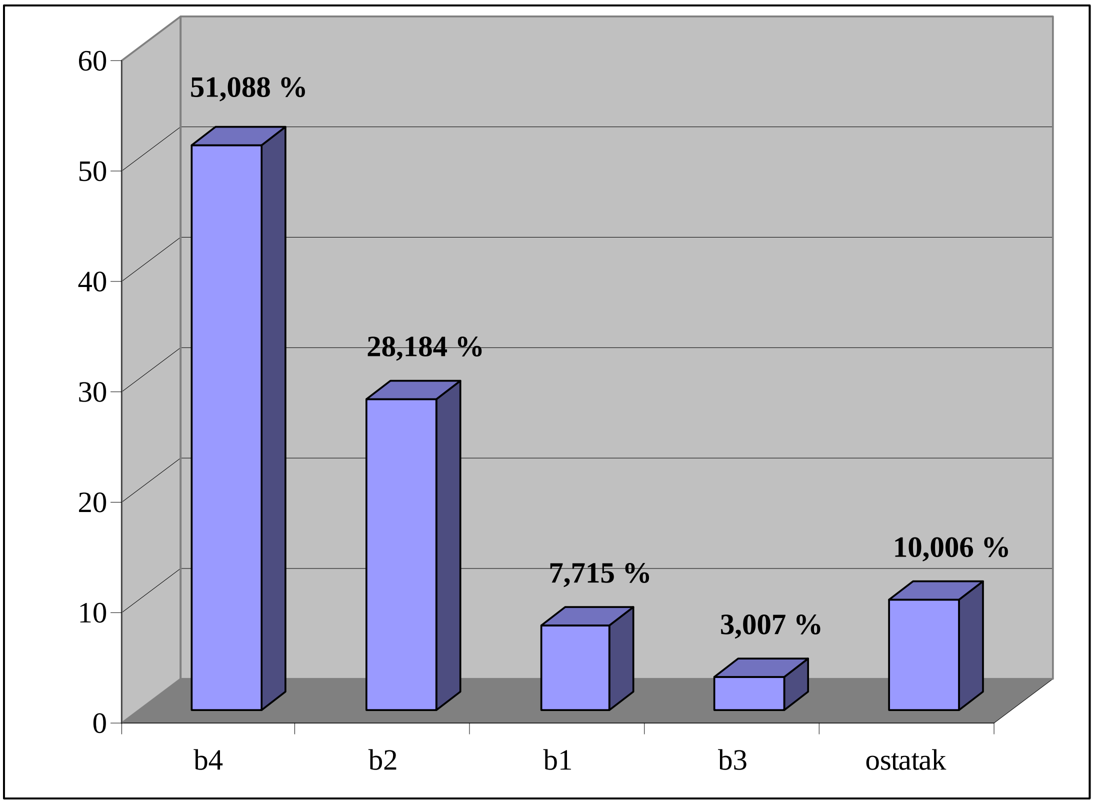
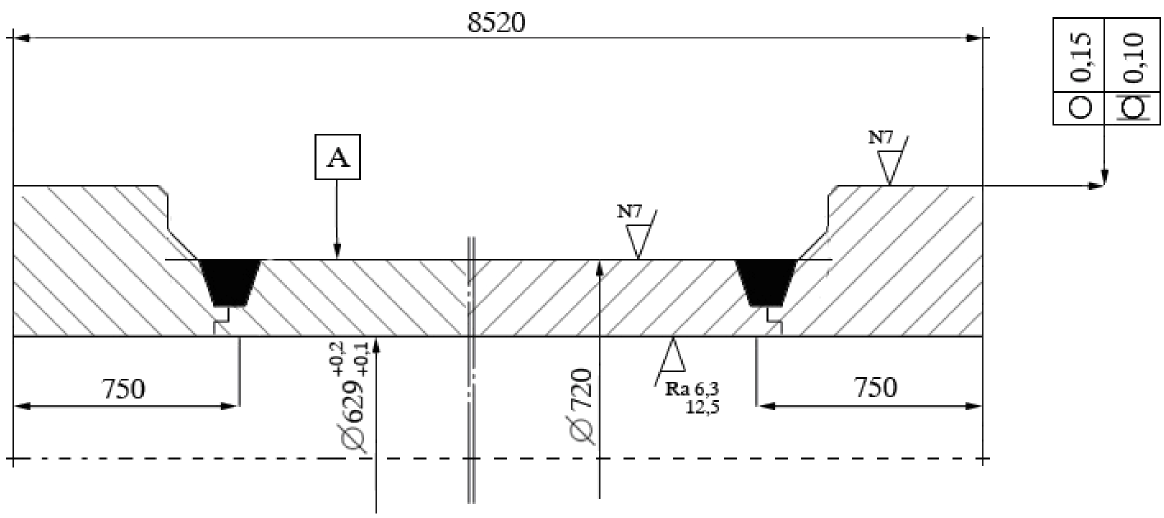


Figure 3: *Ranking and selection of factors influencing the function of arithmetic mean of the profile $R_a=f(v,s,\delta,r)$*

The following machining regimes have been applied in order to expand diameter of Ø629 (+0,1 +0,2) to Ø602: *v*=49 m/min, *s*=0,23 δ=0,23 and *r*=1,2. They provide the value of roughness parameter R_a=9,8-10µm, which corresponds to machining quality N7-N8 (Figure 4). Obtained machining quality R_a and geometric accuracy provide successful honing of the cylinder of diameter Ø630 H8 and surface quality R_a=0,4-0,8 µm.



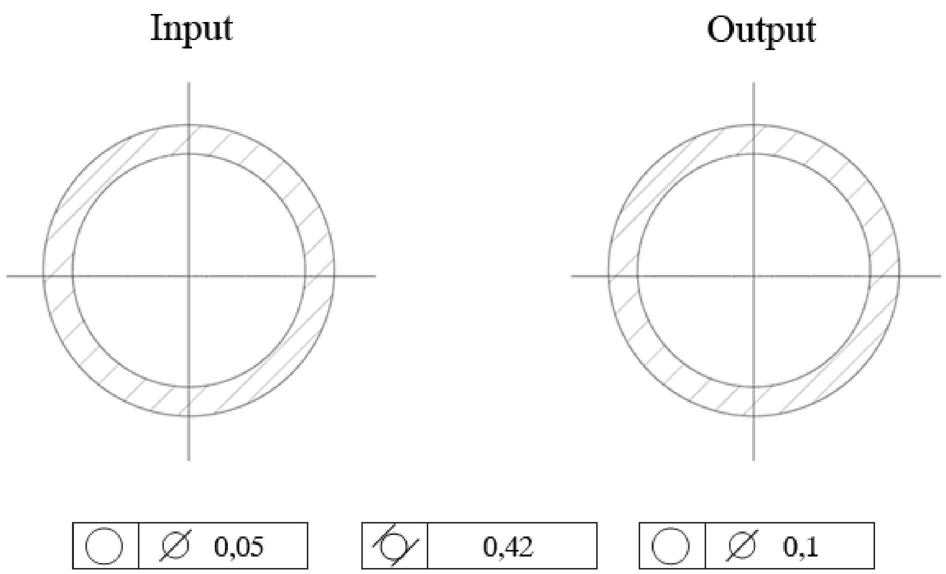


Figure 4: *Quality and geometry of finish machining of the cylinder*

4 CONCLUSION

We can make the following conclusions based on the experimental results which have been obtained and applied under realistic conditions of machining process:

- According to realized and applied analysis of experimental data it is noticeble that the function is influenced by the roundness radius of tool tip *r*, pitch *s*, velocity *v* and cutting debth δ, respectively.
- The pitch *s* and cutting debth δ have a negative influence, i.e. they make machining quality worse, whereas cutting velocity *v* and roundness radius of tool tip *r* have a positive influence and they improve the quality of machined surface and geometric accuracy within allowable tolerance.
- Experimental researches have been done under production conditions and they have been applied to machining of working piece, so they can be reliably used in modelling and optimisation of the processes and machining systems of the kind.

Figure 5: *Machined working piece (cylinder)*

REFERENCES

[1] Box G.E.P, Wilson K.B, On the Experimental Attainement of Optimum Conditions, Journal the Royal Statistical Methods Series B, NO1, New York, 1970.

[2] Dašić, P.: Research of processed surface roughness for turning hardened steel by means of ceramic cutting tools. In: *Proceedings of papers from 2nd World Tribology Congress*, Vienna, Austria, 3 - 7. september 2001. Edited by Friedrich Franek, Wilfried J. Bartz and Andreas Pauschitz. Vienna: Österreichische Tribologische Gesellschaft - ÖTG (The Austrian Tribology Society), 2001, pp. 522. ISBN 3-901657-08-8 (for Abstracts Proceedings in hard copy) and pp. 1-6. ISBN 3-901657-09-6 (Proceedings in electronic form on CD-ROM). Available on Web site: http://www.oetg.at/website/wtc2001cd/html/M-51-29-055-DASIC.pdf.

[3] Dašić, P.: Methodology and Software package CoREMED: **C**hoice **o**f **R**egression **E**quation of **M**ultifactor **E**xperiment **D**esign with and without Repeating. ver. 2.0. Kruševac, 2003.

[4] Dašić P, The choice of reqression equation in fields metalworking. In: *Proceedings of 3rd International Conference: Research and Development in Mechanical Industry– RaDMI 2003*, Herceg Novi, Serbia and Montenegro, 19 – 23 September 2003.

[5] Dašić, P.; Radonjić, S.; Ječmenica, R.; Nedić, B.: Research of the regression functionl of processed surface roughness at the turning by means modern cutting tools. In: *Proceedings of Xth International Conference on Tools ITC'2000*, Miskolc, Hungary, 06 - 08. September 2000. Miskolc (Hungary): Faculty of Mechanical Engineering, 2000, pp. 155-158.

[6] Ekinović, S.: *Obrada rezanjem*, Zenica: Dom štampe, 2001, s. 307. ISBN 9958-42-062-7.

[7] Ivanović, P.: *The researches of new machining system and processes in the production of oil-hydraulic cylinders of great size* (in Serbian language). Ph.D. Dissertation. Kraljevo: Faculty of Mechanical engineering, 2006.

[8] Janáč, A.; Bátora, B.; Baránek, I.; Lipa, Z.: *Technológia obrábania*. Bratislava: Slovenská technická univerzita (STU), 2004. – 288 s. ISBN 80-227-2031-3.

[9] Kalajdžić, M.: *Tehnology of metalworking I* (in Serbian language). 9th Edition. Belgrade: Faculty of Mechanical Engineering, 2004. – 407 pp. ISBN 86-7083-487-1.

[10] Kalpakjian, S.: *Manufacturing processes for engineering materials*. 3rd Edition. Menlo Park (California-USA): Addison Wesley Longman Inc., 1997. – 950 pp. ISBN 0-2018-2370-5.
[11] Kocman, K.; Prokop, J.: *Technologie obrábění*. Brno: Vysoké učení techické v Brně, Fakulta strojního inženýrství, 2001. – 270 s. ISBN 80-214-1996-2.
[12] Kopač, J., *Odrezavanje* (in Slovenian language). Ljubljana: Univerza v Ljubljani, Fakulteta za strojništvo, 1991.
[13] Pantić R, Research of efficiency function parameters in business system. Doctor Thesis, Kruševac: Faculty for Industrial Management, 2007.
[14] Radonjic S.: *Further supplements to investigating finish processing on lathe* (in Serbian language). Dissertation Ph, Belgrade: Faculty of Mechanical Engineering, 1986. – 136 pp. COBISS.SR-ID 27894031.
[15] Spur, G.; Stoferle, T.: *Hanbuch der Fertigungstechnik, Band 3/1 Spanen.* Munchen, Wien: Carl Hanser Verlag, 1980.
[16] Stanić, J.: *Engineering measuring method* (in Serbian language). Beograd: Faculty of Mechanical engineering, 1990.
[17] Stanić, J.:*Introduction into theory of tehno-economic optimization* (in Serbian language). Beograd: Faculty of Mechanical engineering, 1988.
[18] Stanić, J.: *Theory of metalworking I* (in Serbian language). 2nd Edition. Belgrade: Faculty of Mechanical Engineering, 1989. – 268 pp. ISBN 86-7083-108-2.
[19] Tanović, LJ.: *Production technology of modern cutting tools elements* (in Serbian language). Belgrade: Faculty of Mechanical Engineering, 1997. – 99 pp. ISBN 86-7083-294-1.
[20] Vukadinović S, Elements of probability theory and mathematical statistics, Priovreni pregled, Beograd, 1971.