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THE VARIABILITY OF CHOSEN GEOMETRICAL PARAMETERS OF SURFACE LAYER DURING PULL BROACHING PROCESS

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Abstract: *The purpose of this work was to settle a variability of chosen surface layer's geometric parameters after pull broaching in the function of number of machined pieces. Expected effect of this work was to determine the value of chosen parameters of surface roughness after the determined time of pull broaching.*
Keywords: *broaching, surface layer, surface roughness*

1. INTRODUCTION

In the precise technologies, it is very important to achieve appropriate characteristics of the surface layer, because these characteristics are crucial for the quality and time of its exploitation. The outer structure of the detail interacts with the environment and with the other detail, so it has direct influence on the friction and wear processes. Its appropriate forming may extend the exploitation time, so it is important to ensure appropriate characteristics of the surface.

The basic characteristics of the surface layer in large is the description of the geometrical structure of the surface. It is measured, according to the standards, with common linear 2D profilometers giving a profilogram after one pass of the stylus traversed across the surface. Further mathematical analysis of the profilogram enables to obtain a number of parameters describing the surface. The bearing ratio among others predicts the behavior of the surface in contact under workload [2, 5, 6, 9].

It is possible to find relations between the characteristics of the surface layer and the conditions of the technological process. If these relations are known, the characteristics of the work piece would be formed according to the requirements through the appropriate choice of the technology and its parameters. It is proven that the surface layer influences directly process of friction and wear of the rolling and sliding surfaces, contact strength, corrosion resistance, leak proof etc. The exploited detail must be removed mostly because of the abrasive wear and fatigue, and also because of the static strength overload or corrosion. Most of the damages are not by chance, but their source is in the surface layer or just under it. It is estimated that abrasive wear covers 90% of detail damage cases, and the fatigue covers further 8%. It is so because the friction and wear takes place in all machine parts working in movable connections and under surface load [6, 7].

Pull broaching process is widely applied in industry because it is very effective and able to be easy automatized. The process is also used for finishing machining which is very favorable for the surface quality of the details. However, this technology requires the precise and expensive tools. Therefore, it is important to examine the cutting ability worsening process and its influence on the machined layer parameters in order to perform proper diagnostics of the pull broaches and to ensure its effective usage.

Nowadays, the pull broaching is widely used as a highly precise machining process in mass production, mainly in motor industry and in mechanical engineering. The development of this machining method in production of precise details is the result of its high effectiveness.

2. THE SURFACE LAYER OF THE PULL BROACHED DETAILS

Precise pull broaching process requires very good state of the tool wedges, the cutting fluids with dominant cooling components, and the appropriate machine tool [1, 4, 8]. When the thin-walled details (like bushing) are under machining, the small thickness of the one cutting wedge should be applied to avoid the elastic strain of the detail. The shape of the pull broached detail is formed by the pull broaches shape; therefore any inaccuracy of the tool shaping will affects the dimensions, the shape and the surface structure of the machined detail.

With the pull broaching technology it is possible to obtain the surface of R_a = 0,16÷2,5 µm roughness when the smooth and very smooth surface is required. When the higher roughness is not allowed, the machining with only roughing wedges is enough. The surfaces with roughness R_a = 1,25÷5 µm should be machined with pull broaches equipped with both roughing and finishing wedges, while the highest precision surface with very small roughness should be machined with using the burnishing wedges, too[3].

Determination of variability of chosen geometrical parameters of surface layer after broaching in the relation to the number of machined details was the aim of the research.

3. EXPERIMENTAL PART

The examinations of the process have been performed in the factory of FZN Marbaise Leroy-Somer Ltd. which produces the driving units. The pull broaching process has been carried out with horizontal broaching machine of 7A540 type, relatively simple in operation. The operator has to fix manually the work piece in the appropriate locating pad placed in the disk holder (Fig. 1a).

a) b)

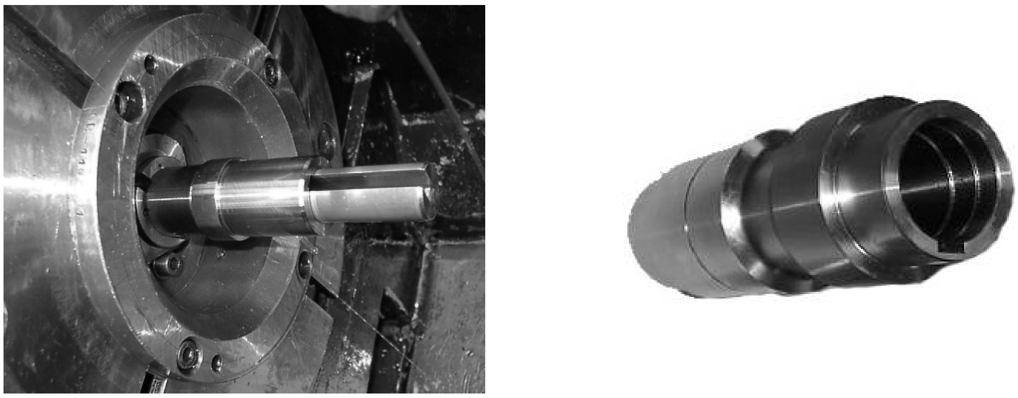


Fig. 1. *The pull broached detail: a) with tool leading pad, b) the detail with pull broached groove inside*

The groove at the inner cylindrical surface has undergone the pull broaching process (Fig. 1a). This detail is a part of the drive produced by the factory (Fig. 2).

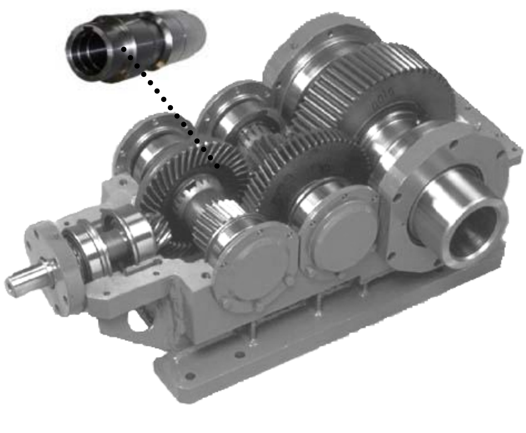


Fig. 2. *The transmission produced by the FZN Marbaise Leroy Somer factory*

The previously prepared details underwent the pull broaching process. The machining of the groove is one of the final operations, because the outer cylindrical surface is a base surface for fastening the detail in the holder. It is required that the front surface is perpendicular to the machined orifice.

The bar broach was applied, made out of steel SK5M with hardness 62 HRC. It is a highly ductilable steel with very good cutting characteristics, highly resistant to tempering. It is used for difficult - to - cut materials: hard and austenitic steels, for the machining of the wheel sets or hoops, cast iron details and so on. Out of it are being made also planning and turning tools, drills and mills, as well as the form tools. It is possible to harden it up to the 64 HRC.

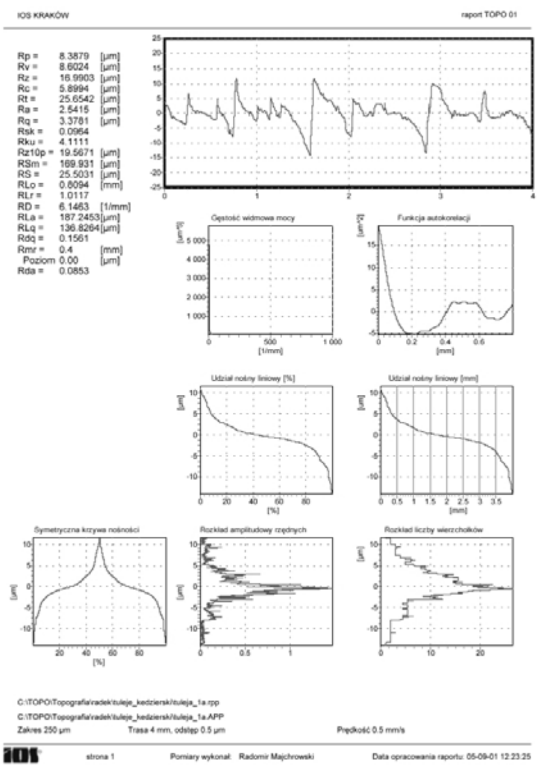
Every hundredth machined detail had been examined, beginning with the first hundredth, in unchanged industrial conditions. The samples had been signed according the order of machining (each hundredth sample). The measurement of 12 details from 100th to 1200th had been performed. The roughness had been measured in the Division of Metrology and Measuring Systems of Poznan University of Technology. The profilometer TOPO L50 (Fig. 3) had been used for measurement, with vertical measuring range 250 μm. The assessment length of the measuring was 4 mm, and the minimal step between the surface irregularities was 0,5 μm. After the roughness profile P was recorded, it underwent the filtration process, and many parameters were calculated. Mainly the basic amplitude parameters of roughness like R_z, R_a, R_q, R_t, R_{sm}, R_{ku}, R_{sk} and of waviness like W_z, W_a, W_t were taken into account.

Fig. 3. *The measuring probe placed on the examined surface*

4. ANALYSIS OF THE OBTAINED DATA

After the measurement was carried out, the results for each of 12 samples were obtained. Fig. 4 presents unordered rough obtained data.

a) b)



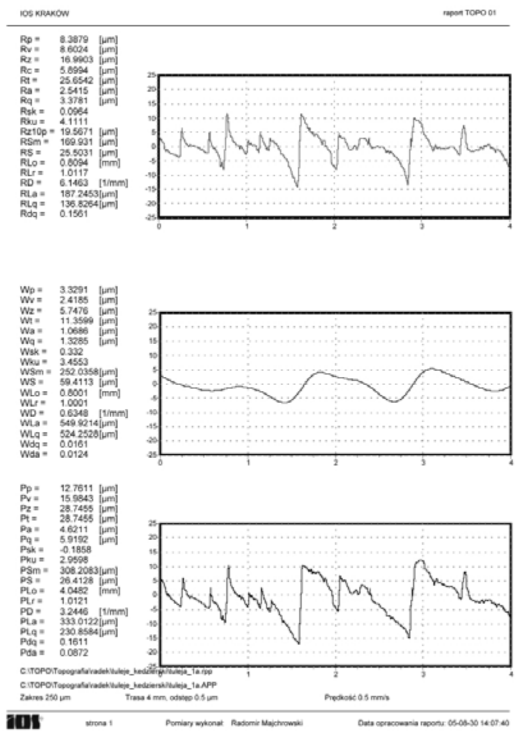


Fig. 4. *The example of the measuring results (the sample No 1000)*

The table 1 presents the values of the chosen roughness parameters for each measured detail, hence dependent on the number of machined work pieces. Figures from 5 to 10 present these data graphically.

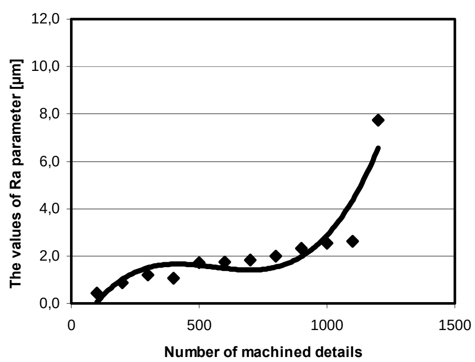


Fig. 5. *The values of R_a parameter for the samples in machining order*

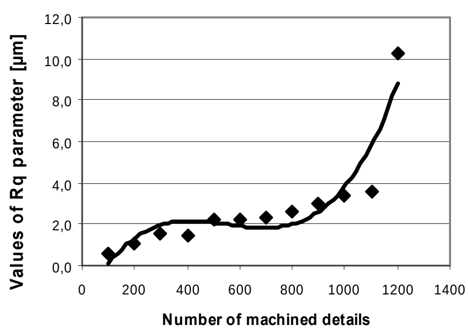


Fig. 6. *The values of R_q parameter for the samples in machining order*

The R_q parameter is a statistical deviation with value dependent mostly on single peaks and valleys. However, this parameter gives no information on the distribution of peaks; also it is impossible to distinguish between the influence of peaks and influence of valleys on the final value of R_q. The graph, however, shows the continual rise of the parameter which proves the continual worsening of the surface quality with the rise of the number of machined details.

Table 1. The parameters of the roughness for measured samples

No of sample	R_a [μm]	R_q [μm]	R_t [μm]	R_{sk}	R_{Sm} [μm]	R_{ku} [μm]
100	0,4411	0,5905	5,3458	-0,4722	72,2497	4,1189
200	0,8651	1,107	6,8803	-1,0650	127,035	4,2321
300	1,2048	1,5037	14,7933	-0,2081	180,2426	3,5754
400	1,054	1,417	14,3113	-0,0719	165,5165	4,4587
500	1,7102	2,254	20,8541	-0,2599	172,8949	3,1489
600	1,7624	2,2525	17,9041	-0,2184	159,0542	2,7996
700	1,8414	2,3488	15,8693	-0,1615	136,9122	3,3103
800	1,9896	2,6292	17,4550	-0,1137	-0,1137	4,0783
900	2,3106	3,0187	19,7194	0,3553	150,5533	3,7278
1000	2,5415	3,3781	25,6542	0,0964	169,931	4,1111
1100	2,6106	3,5527	37,2329	0,2773	272,0827	4,3889
1200	7,7277	10,2836	34,1361	0,4117	272,0827	3,4857

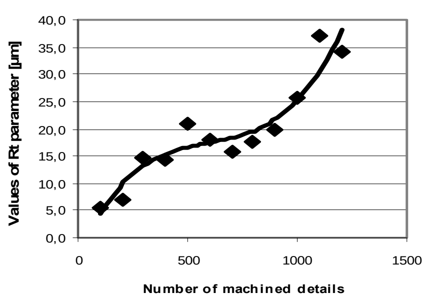


Fig. 7. *The values of R_t parameter for the samples in machining order*

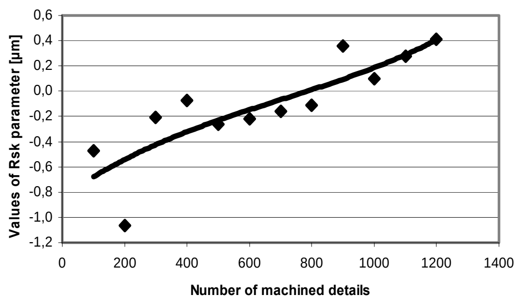


Fig. 8. *The values of R_{sk} parameter for the samples in machining order*

The measure of the asymmetry of the profile about the mean line is the parameter R_{sk}, called skeweness. Here (see Fig. 8) it has negative value up to 800th sample which means that the material is concentrated close to the peaks (the surface is like plateau with few valleys). For larger number of machined details R_{sk} rises to positive values, which means the material is concentrated lower (the valleys with few sharp peaks).

The appearance of the sharp peaks is confirmed by the kurtosis parameter R_{ku}. The distribution of the parameters lies above number 3; hence, it is more slender than normal distribution (Fig. 9). However, none of those parameters gives information on the number or distribution of the peaks and valleys in the measured profile.

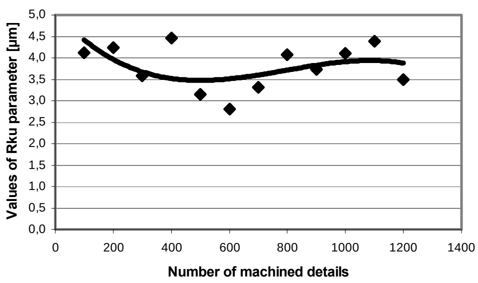


Fig. 9. *The values of R_{ku} parameter for the samples in machining order*

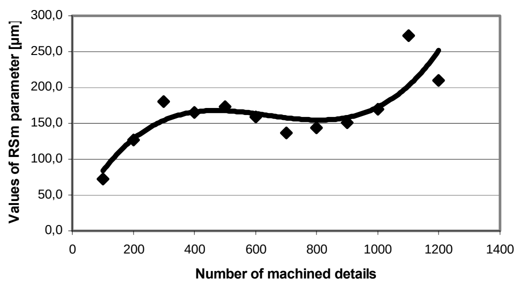
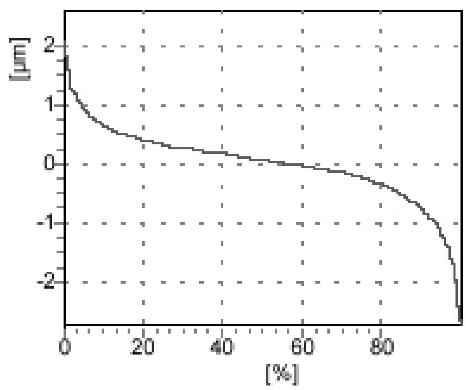


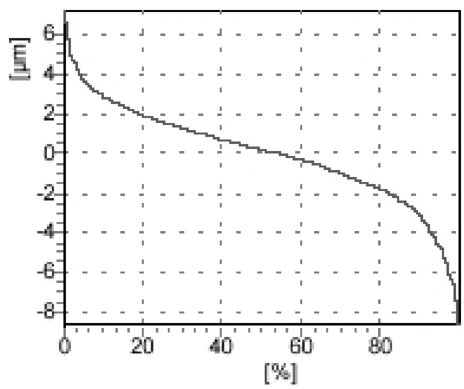
Fig. 10. *The values of R_{Sm} parameter for the samples in machining order*

The graphs of the bearing ratio for the successive samples indicate the increase of the sharp peaks' number (Fig.11) which leads to the decrease of the bearing ratio on the mean line level, i.e. to the worsening of the surface quality. In the movable contact, the sharp peaks cause the increased friction and fastened wear of the detail [9].

a)



b)



c) d)

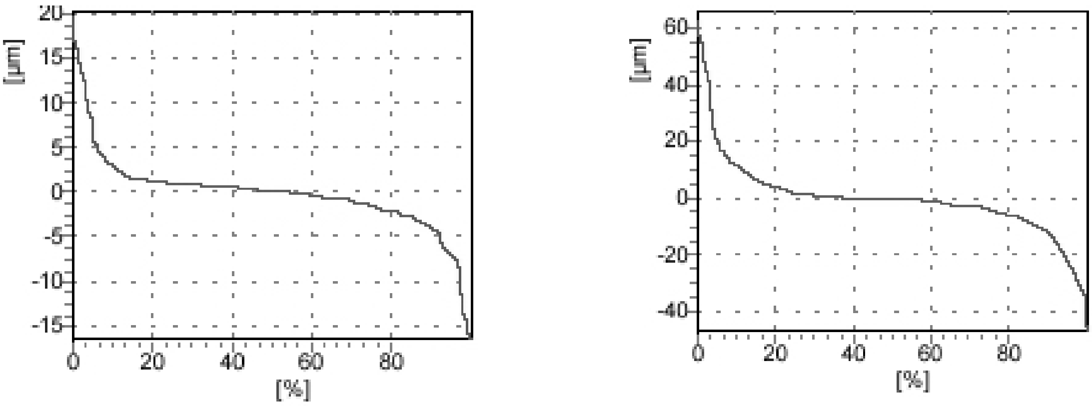
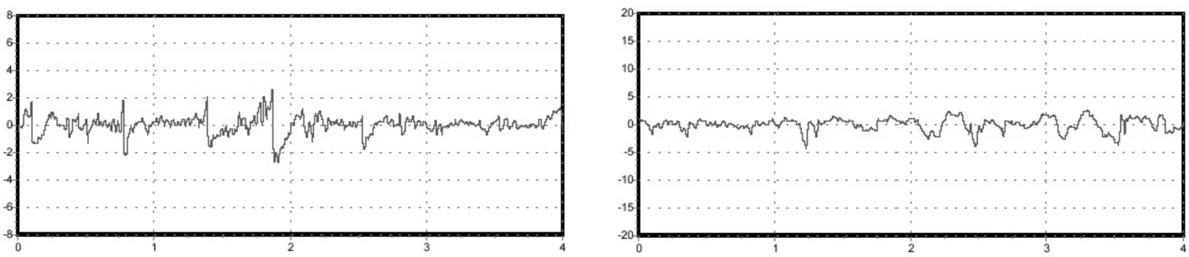


Fig. 11. *The bearing ratio graphs for the samples No: a) 100, b) 700, c) 1100, d) 1200*

5. CONCLUSIONS

Despite the fact, that the graphs differ not much from one another, they represent definitely different surfaces. The height of the profile of 100th sample is 5 μm, while the height of the 1200th sample is seven times larger (34,1 μm). It is clearly seen in the recorded profiles shown on the Fig. 12. One can see the distribution of the peaks, and the increased sharpness, as well as the deepened valleys in the „landscape”.

a) b)



c) d)

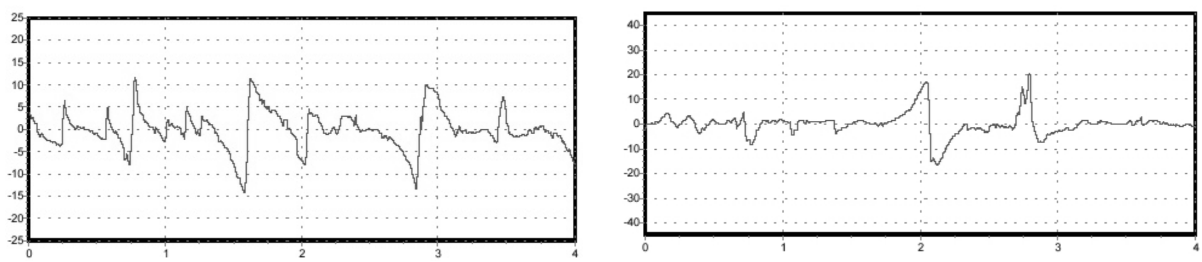


Fig. 12. *Roughness profiles for successive samples (No 100, 200, 1000, 1100)*

The literature analysis and the obtained results lead to the conclusion that the wear of the cutting wedges caused by increased number of machined details affects the quality of machined surface and worsens the exploitation characteristics of machined detail. To ensure the required quality, the appropriate supervision and regeneration of the cutting wedges must be performed.

The analyzed number of the pull broached details indicated the rise of the roughness parameters of the machined surface caused by the cutting wedge wear. R_a and R_q parameters prove the worsening of the surface quality after about 600th machined detail. Parameters for 1200th sample are considerably different from others because of the cutting tool wear. The fact was not proved by the measurement of further details; because the tool was given to regeneration after the 1200th detail was machined. To prove the conclusions, the 200 - 400 more details should undergo the machining and measurement. However, it was impossible because of the common sense, as the examinations were performed in the industrial conditions. Normally, the visible signs of the cutting wedge wear appear after about 1500 passes of the tool. Then the whole life cycle of the pull broach may be analyzed.

The further investigation should be directed towards the determination of the direct relation between the cutting wedge wear and the state of the surface layer. To obtain this, the parallel measurement of the surface layer parameters and the wedge wear parameters should be performed. Unfortunately, the industrial conditions in FZN Marbaise factory gave no opportunity for cutting wedge measurement during the process, because it would cause the interruption in the production process.

Since more than ten years, the examinations of geometrical structure of the surface are widened by 3D measurement. The measurement of several tens and hundreds of profiles replaced the traditional analysis of just one profile. The obtained data are processed by the computers, giving the 3D images, contour maps, 3D parameters and bearing ratio for the surface of several square millimeters. It should be considered, in what extend stereometrical analysis is better and more accurate, when it should be applied and when it is not necessary. The problem deals mainly with the repeatable-machined surfaces like turned surfaces. However, when the results differ sufficiently, it seems to be necessary to apply 3D analysis in order to describe the surface properly.

REFERENCES

[1] Forst handbook, *Hints on broaching*. Oswald Forst GMBH, Solingen 1973.
[2] Górecka R., Polański Z., *Metrologia warstwy wierzchniej*. Wydawnictwa Naukowo-Techniczne, Warszawa, 1983.
[3] Kędzierski T., Wieczorowski K., *Nadzorowanie stanu ostrzy skrawających przeciągacza*. International Workshop „CA Systems And Technologies", Vyd. Zilinska Univerzita, Zilina 2003, s. 58-61.
[4] Miracki J., *Przeciąganie*. WNT, Warszawa 1962.
[5] Oczoś K. E., Lubimov V., *Struktura geometryczna powierzchni*. Rzeszów 2003.
[6] Starzyński G., *Warstwa wierzchnia i jej modelowanie*. IPPT PAN, strona internetowa. http://www.ndt - imbn.com
[7] Web site: *Fizyczne aspekty diagnostyki*: http://wm.atr.bydgoszcz.pl
[8] Web site: www. broachingmachine.com
[9] Wieczorowski M., Cellary A., Chajda J., *Przewodnik po pomiarach nierówności powierzchni, czyli o chropowatości i nie tylko*, Zakład Poligraficzno - Wydawniczy M-Druk, Poznań, 2003.