

RESEARCH OF THE SURFACE ROUGHNESS CREATED DURING PULL BROACHING PROCESS

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The paper characterizes the surface layer roughness formed in the process of pull broaching. The factors influencing the roughness of a workpiece subjected to pull broaching were analyzed. As a result of the measurements the basic roughness parameters as well as isometric images of the surface layer for different samples taken from production were obtained. 3D images were also obtained in the investigations of the surface layer of pull broached driving plate.

Key words: broaching, surface layer, roughness

Istraživanje površine hrapavosti površine nastale postupkom provlačenja. Rad obrazlaže karakteristike hrapavosti površinskog sloja nastalog procesom povlačenja. Analizirani su utjecajem faktori hrapavosti obradka nakon postupka provlačenja. Osnovni parametri hrapavosti kao i izometrijske slike površinskog sloja različitih uzoraka iz proizvodnje su dobiveni eksperimentalnim mjerenjem. U istraživanju površinskog sloja su također dobivene 3D slike površinskog sloja.

Gljučne riječi: povlačenje, površinski sloj, hrapavost

INTRODUCTION

At present, the industry and the market require products to possess the best utilizable properties possible. The setting up of higher and higher demands is caused by the development of motor-car industry, air-industry, space-industry, precision engineering and other advanced technologies. At the same time a great emphasis is put on the reduction of production times, increasing the speed of processing, as well as seeking new technologies and expanding the old ones. In precise technologies the utilizable qualities of surface layers of workpieces are very important, since they are a major influence on the quality and working life of a device. With the help of pull broaching it is possible to obtain all shapes by use of linear motion of the tool. Pull broaching advantageously influences the condition of the surface layer of the machined workpieces.

Surface layer has direct influence on friction and wear processes of rolling and sliding surfaces [1, 2], contact strength, corrosion resistance, tightness etc., therefore it is so important to assure of its appropriate formation, what influences the prolongation of exploitation time of a unit [3-6].

SURFACE LAYER AFTER THE PROCESS OF PULL BROACHING

Because the shape of the tool is transformed from an object, all tool errors influence both dimensional and shape quality as well as the condition of the surface. With the help of pull broaching it is possible to obtain surfaces of roughness ranging from $R_a = 2,5 \mu\text{m}$ to $R_a = 1,25 \mu\text{m}$ in exact processing as well as, depending on needs, to $R_a = 20 \mu\text{m}$ - in case of roughing [7].

While analyzing the literature it is possible to state that the following factors influence the roughness of surface after pull broaching:

- the condition of cutting edges of the pull broach,
- the cutting fluid and type of cooling [4],
- the value of tool rake and orthogonal clearance angle,
- the thickness of machined layer by one cutting wedge [1, 2, 5],
- the number of concurrently cutting wedges,
- construction and condition of the broaching machine [7],
- the characteristics of the machined material: mechanical, physicochemical and structure [4, 5, 7].

Among the mentioned factors the condition of cutting wedge is of greatest influence. All the errors of the condition of cutting wedge impair the condition of the machined surface. Therefore, in practice, the tools are subjected to control and regeneration at a specific period of time.

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EXPERIMENTAL INVESTIGATIONS

Methodology

The subject of investigations of the surface layer was the driving plate produced as a distributor unit of DPA type injection pump made on Lucas company license used in engines of: tractors, delivery vans, buses, working machine engine generators. The mentioned plate is produced by Wytownia Sprzetu Komunikacyjnego Poznan (Poland).

Regarding the assurance of appropriate accuracy the semi-manufactured part in the form of plate (Figure 1) was subjected to pull broaching.

Pull broaching was executed on perpendicular broaching machine with hydraulic drive manufactured by an English company MATRIX type BVR 15-48. During the machining the cooling - lubricant oil sulfofrezol 1 was applied.

Samples were marked in order of pull broaching (every hundredth sample in unchanged machining conditions) and subsequently subjected to measurements of roughness in the Division of Metrology and Measuring Systems at Poznan University of Technology.

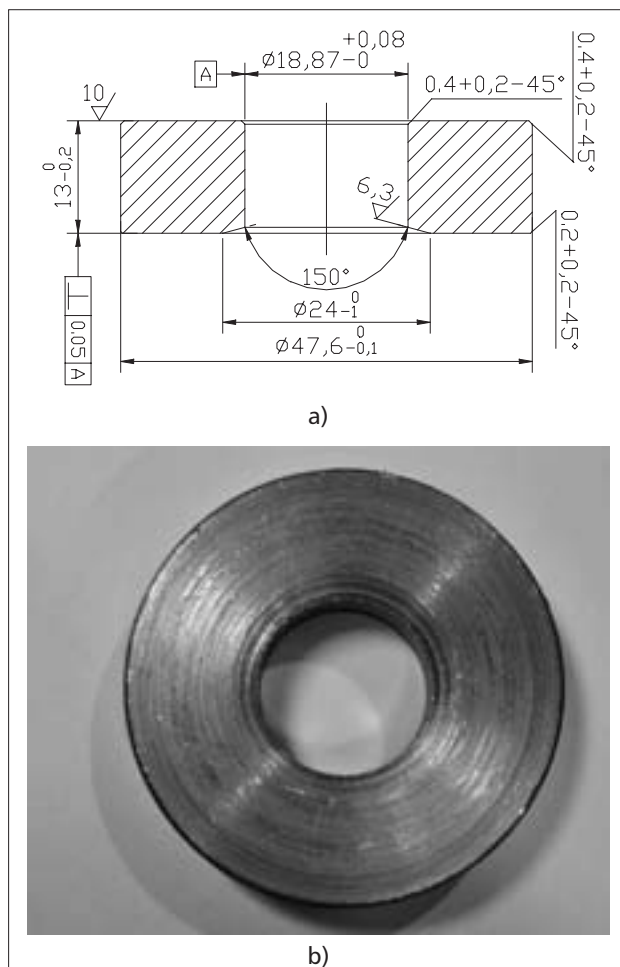


Figure 1 The drawing of the machined semi-manufactured part (a); example of the investigated test piece of the driving plate (b)

The measurements of surface roughness were conducted on a profilometer Perthometer 58P equipped with FRW - 750 head and measuring probe 6851410. The measuring perpendicular range of the device, in which the probe can move in allowable limit of error, was 125 μm . The side length of the sampling area was 4 mm. 33 sections of the surface were measured giving the basic parameters of roughness such as: R_z , R_a , R_q , R_t , R_{sm} and R_{sk} .

Due to dispersions in individual measurements the following are marked for each parameter: *mean value*, the value of *standard deviation S*, *MAX - MIN value*, *MAX value*, *MIN value*.

In the studied samples the following isometric images were calculated: positive and negative image of the surface as well as the waviness of the surface and additionally 3D image.

Presentation and analysis of results

From the taken test samples the basic parameters of roughness were obtained which were then represented in form of tables (Figure 2) and graphs, thanks to which a wider analysis of the individual roughness parameters can be conducted.

On the basis of measurements' results the graphical charts of relationship between the roughness parameters and the sample number were obtained.

The graphs show that in the initial pull broaching phase (up to 600 pieces) the values of roughness parameters R_z , R_a , R_q , R_t and R_{sm} grow, and then they begin to fall, as exemplified by R_a parameter below (Figures 3, 4).

The R_a parameter for the arithmetical mean of ordinates of roughness section acts similarly to R_z . This parameter is often in use, but it does not provide the information about the shape of the section. It is similarly insensitive as R_z on all valleys and elevations.

The parameter of square average of roughness section ordinates, R_q is the standard statistical deviation, and the individual elevations and valleys of the section influence

	PARAMETER	STATISTICS N=33				
		X	S	R	MAX	MIN
	LC GS 0,800 mm					
1	R_z μm	16,26	2,77	10,32	21,78	11,46
2	R_a μm	2,96	0,62	2,13	4,24	2,11
3	R_q μm	3,70	0,73	2,44	5,17	2,73
4	R_t μm	20,30	4,04	15,64	29,67	14,03
5	R_{sm} μm	210,7	66,37	250,0	400,0	150,0
6	R_{sk} μm	-0,153	0,314	1,176	0,401	-0,776
7	R_{dq} μm	0,347	0,021	0,007	0,393	0,386
8	R_{lq} μm	67	13	44	92	49

Figure 2 Exemplary results of measurements for sample number 401

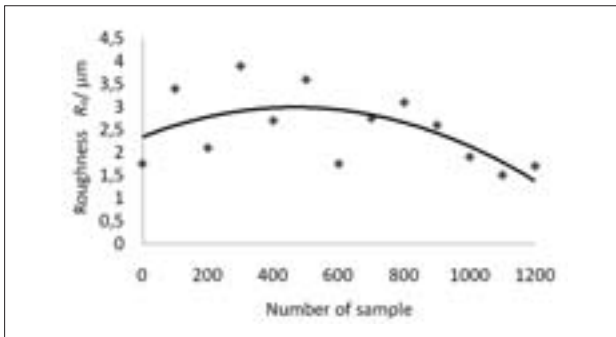


Figure 3 Diagram of R_a parameter for mean values X

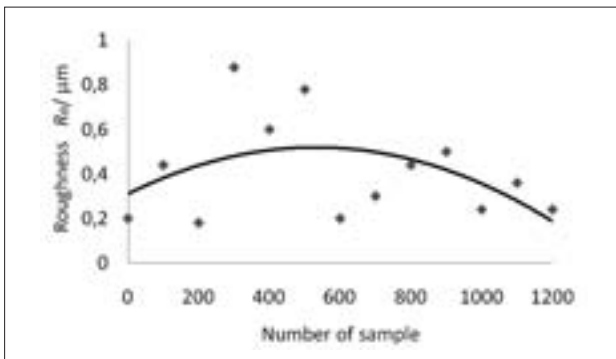


Figure 4 Diagram of R_a parameter for standard deviation values S

its value more significantly. However, this parameter does not provide information about distribution of peaks. It is also not possible to distinguish whether the specified parameter value is caused by a peak or an elevation.

The total height of roughness section, R_t is sensitive to individual elevations and valleys. Therefore, in comparison to R_q and R_a the value of R_t parameter falls starting with the 600th sample more softly. R_t higher than 0,5 μm implies that the peaks are acute.

The average width of grooves of section roughness elements, R_{sm} is useful in characterizing the functional behavior of the workpiece. The average width of roughness section units grooves, R_{sm} shows that up to the 500th sample the distance of grooves (the spacing) grows and then it decreases. In this case the individual high elevations do not have any significant influence on the R_{sm} parameter.

The R_{sk} parameter illustrates the symmetry of distribution of the section ordinates in relation to the average line. The negative value indicates concentrations of material in the vicinity of peaks of the section, which marks the surfaces of elevated plane shape. This parameter in case of symmetrical section has zero value. The received exemplary results are represented by the following graphs (Figures 5, 6).

The coefficient of asymmetry, R_{sk} of the roughness section has in this case positive value, which means that the studied section has acute elevations and valleys. From the diagram of standard deviation it is visible how the parameter grows, which indicates the growth of elevations and the deterioration of the surface quality. In

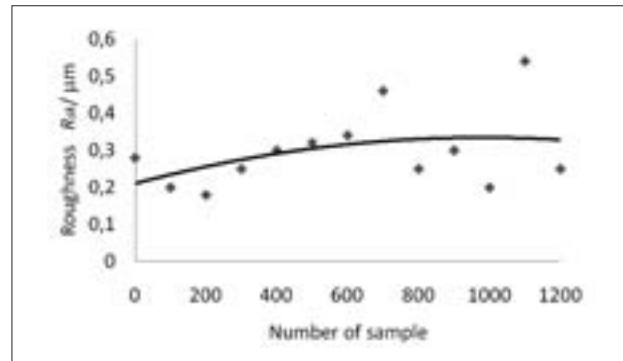


Figure 5 Diagram of R_{sk} parameter for the values of standard deviation S

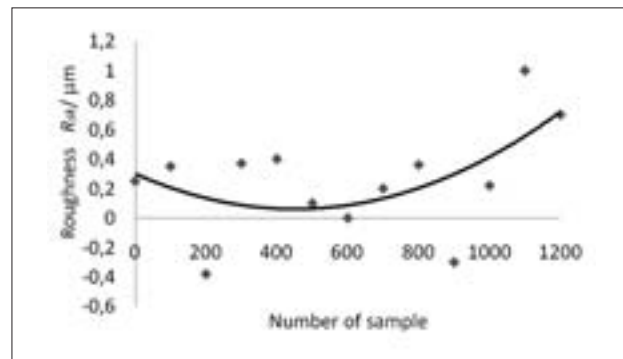


Figure 6 Diagram of R_{sk} parameter for the values Max

case of maximum values R_{sk} initially diminishes and subsequently grows violently, being a further evidence of the decrease in surface quality.

The exemplary isometric images of waviness are presented in Figures 7 and 8. From two (samples 201 and 1101) selected images of waviness it is visible that the surface properties deteriorate. By comparing them it is possible to state that the surface of the first one is far more flat, while in the second one large individual valleys are visible, which diminish the quality of the surface.

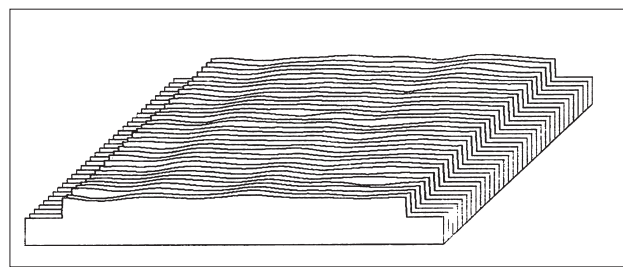


Figure 7 The image of waviness for sample 201

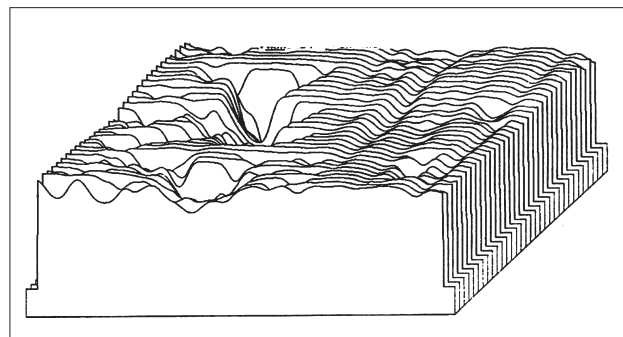


Figure 8 The image of waviness for sample 1101

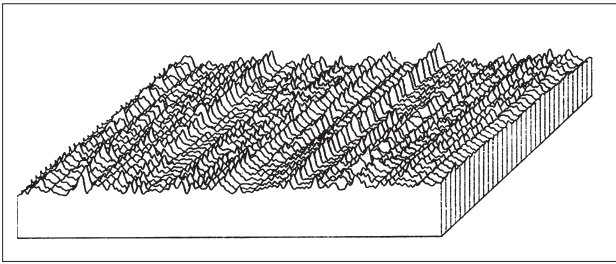


Figure 9 Isometric negative image of sample 101

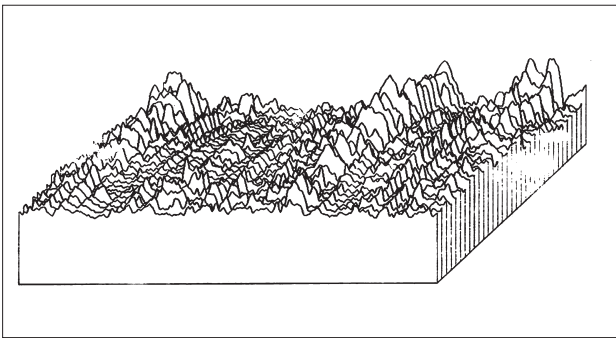


Figure 10 Isometric negative image of sample 1201

The exemplary isometric negative images are presented in Figures 9 and 10. The inverse displays show the appearance of surfaces of individual samples. It is possible to state on their basis how the surface of the pull broached workpiece has deteriorated. Samples from 101 (Figure 9) to 701 are characterized with surface of good roughness properties.

However, samples from 801 to 1201 have surfaces of worse properties. Sample 1201 in particular (Figure 10) has elevated planes and deep valleys which practically disqualify its surface.

Figures 11 and 12 show the three-dimensional images of samples 201 and 1101, which unambiguously illustrate the differences in geometrical structure of the surface.

CONCLUSIONS

The conclusion relating measurements has to be the following: basic roughness parameters do not reflect in this case the real state. From the investigations of roughness parameters it appears that in the initial phase (up to sample 600) the parameters grow and then decrease, which contradicts the actual state. Therefore, spatial 3D images allow better understanding of surface. For some surfaces, 2D parameters are sufficient and do not require broadening to the third dimension. The contact surfaces most often do not exceed several per cent. In such case the measurement of a given section can understate the height of irregularities. One passage of probe cannot provide the complete image of real surface and sometimes, as it took place here, it can be outright misleading. Such passage can contain information which is not representative for the surface as a whole. Measurement of the parameters of surface stereometry would be a

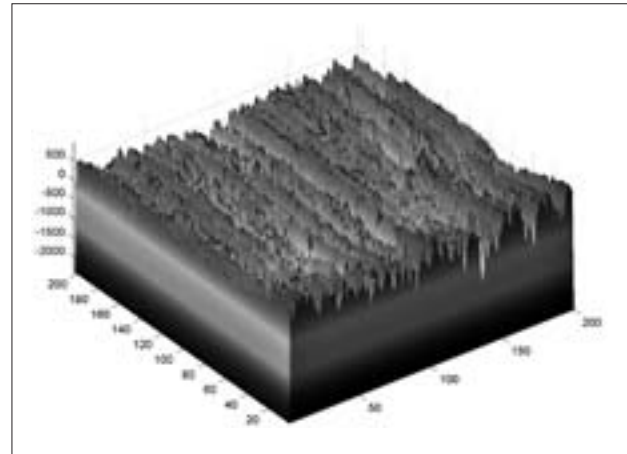


Figure 11 3D image of the surface of sample 201

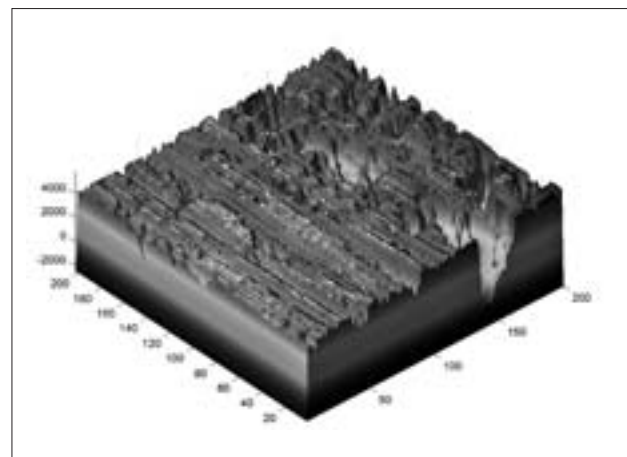


Figure 12 3D image of the surface of sample 1101

good solution in this case, but at present these parameters are not yet standardized.

REFERENCES

- [1] Kawalec M., Rybicki M., *Surface Formation during Face Finish Milling of Hardened Steels*, Archives of Mechanical Technology and Automation, Poznan, 2002, 22(2002) 61-66.
- [2] Kawalec M., *Roughness and Structure of Surface of WNL Steel after Laser Hardening and Turning*, Archives of Mechanical Technology and Automation, Poznan, 2002, 22(2002) 13-19.
- [3] Starzynski G., *Surface Layer and its Modeling*, IPP PAN, (in polish).
- [4] Kiepuszewski B., Legutko S., Wiczorowski K., *Cutting of Metals*, Publishing House of Poznan University of Technology, Poznan 1980 (in polish).
- [5] Legutko S., Nosal S., *Forming of Technological Surface Layer of Machine Parts*, Center of Scientific Publications of Polish Academy of Science, Poznan 2004 (in polish).
- [6] Gorecka R., Polanski Z., *Metrology of Surface Layer*, Scientific – Technical Publisher, Warsaw, 1983 (in polish).
- [7] FORST HANDBOOK, *Hints on broaching*, Oswald Forst GMBH, Solingen 1973.

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