Application of function of quality losses G. Taguchi for study of roller burnishing parameters

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Abstract. The results of roller burnishing parameters analysis with self-acting feed are presented in this paper. Method of parameter process design based on the quality losses G. Taguchi function was applied. The following controlled parameters were assumed: Ra – roughness parameter before roller burnishing process, w - interference between a roller and a burnished sample. k – multiplication factor of each sample point deformation, V – burnishing velocity. The following factors were assumed as process disturbances: treated material hardness and lubrication of burnished surface. Basing on experimental results it was found that strongest influence (in tested range of parameters variations) on roller burnished surface roughness has initial surface roughness and burnishing velocity. These factors also showed have the smallest resistance to process disturbances.

1 Theoretical introduction

Basing on the achievements of mathematical statistics and classical methods of experimental design, Taguchi developer his own methods of experimental design and results analysis [1-4]. Taguchi created among the others theory of quality losses function based on experimental design. Decrease in the number of experiment with respect to traditional experiment is the fundamental advantage of Taguchi's approach. However selection of suitable factors combination causes controversy.

The roller burnishing is one of the most often used methods of burnishing of cylindrical outer surfaces. Usually it is used for cold hardening. Smoothness burnishing is the other application. This kind of burnishing is applied when required shape and dimensional accuracy was obtained in previous treatment and very good smoothness of burnished surface is required. Smoothness roller burnishing is used to finish machine parts in which grinding pollutions in surface layer are unacceptable or for elements which can't be finished with too strong forces. For mentioned above elements ball burnishing or slide diamond burnishing are usually used. However these finishing methods are characterized by very small productivity and whenever possible the roller burnishing should be used because of its this higher productivity. In order to obtain higher shape-dimensional

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accuracy the roller burnishing should be applied with rigid pressing of tools (rollers) [5, 6, 16-18].

2 Description of the research problem

The information mentioned in the introduction and observed in last years technology the tendency to eliminate of abrasive machining methods for machine parts operating under sliding friction conditions (because of disadvantageous surface layer state after abrasive machining) caused that problems connected with design and manufacture of device for shaft roller burnishing are now present-day problems in Department of Manufacturing Processes and Production Engineering in Rzeszow University of Technology. This device makes smoothness shafts burnishing in automatic machining line possible, with the analysis of process parameters effects and parameters optimisation [7-15, 19, 20].

This paper presents attempt of determination of machining process selected parameters influence on achieved surface roughness of cylindrical outer elements after roller burnishing.

3 The analysis of rolling burnishing parameters with Taguchi method application

In order to analyse of the rolling burnishing process (described in references [5, 7] using Taguchi method the following control factors were selected:
1) Ra – surface roughness parameter before roller burnishing (µm),
2) w – depth of tools (rolls) interference into burnished surface (µm),
3) k – deformation multiplicity of each point of burnished surface,
4) V – burnishing velocity (rev/min)/

As a disturbances the following factors were selected:
1) HRC – hardness after quenching and tempering,
2) lubrication before roller burnishing (samples were lubricated and no lubricated). Cylindrical turned specimens of about 90 mm length were made from 1.503 steel. The number of repetitions was three. Diameter of specimen was measured in two perpendicular directions using micrometer and basing on the average value of both results the interference of tool was calculated.

Surface roughness was measured by Surtronic 3+ surface measurement gauge. High-pass filtering was done with 0,8 mm cut-off. The assessment length was 4 mm. Surface roughness R_a parameter of each specimen before and after roller burnishing was calculated in the same place as arithmetic average from 4 measurements in axial and circumferential shaft directions, in centre part of specimen.

The roller burnishing tests were realized on special centreless roller burnishing machine constructed and produced in Chair of Manufacturing Processes and Production Organization of Rzeszow University of Technology. This machine is characterized following features: is assigned to finish burnishing of shafts, turn axis of rollers is inclined in relation to treated shaft axis and pressing of rolls is realized by rigid method. The machine is detailed described in [5].

Controlled (input) parameters signatures were as follows: A = R_a, B = w, C = k, D = V and disturbance factors signatures were as follows: X = HRC and Y = lubrication. Theoretical upper values of parameters (sign. +1 or MAX) and lower values (-1 or MIN) are presented in Tab. 2. The effect of roller burnishing parameters ob surface roughness was determined basing on Taguchi method design of experiment. Table 2 shows plan and obtained results of experiment. Arithmetical mean value of the Ra parameter was denoted as Yi and calculated from 3 preceding columns, however each from these results is arithmetical mean from 20 measurements (5 cut-offs x 4 circumferential measurement).

Table 1. Maximum and minimum parameters values.

PARAMETER	R_a [µm]	w [µm]	k [-]	V [r.p.m.]	HRC	Lubrication
	A	B	C	D	X	Y
MAX (+1)	5.7	105	16	150	50	YES
MIN (-1)	1.5	11.5	4	50	32	NO

Table 2. The results of roughness measurement and their average values (Yi) and values of SN index.

					X	-1	+1	+1		
	A	B	C	D	Y	-1	-1	+1	Y_i	SN_i
1.	-1	-1	-1	-1		0.90 0.67 0.79 *0.787*	1.73 1.23 1.03 *1.330*	1.56 1.42 1.24 *1.407*	1.175	-1.632
2.	-1	-1	-1	+1		1.11 0.93 0.82 *0.953*	0.76 0.57 0.41 *0.580*	0.78 0.46 0.51 *0.583*	0.705	2.772
3.	+1	+1	-1	-1		2.64 2.54 2.40 *3.175*	1.05 1.08 0.99 *1.040*	0.95 1.11 0.94 *1.000*	1.738	-6.079
4.	+1	-1	+1	-1		5.39 5.42 5.40 *5.400*	2.05 2.09 1.98 *2.040*	1.95 2.13 2.00 2.027	3.156	-10.961
5.	-1	+1	+1	+1		0.28 0.25 0.27 *0.267*	0.37 0.51 0.53 *0.470*	0.47 0.61 0.51 *0.530*	0.422	7.189
6.	+1	+1	+1	+1		0.36 0.37 0.55 *0.427*	1.73 1.23 1.03 *1.330*	1.32 1.13 1.09 *1.180*	0.979	-0.471

The values of SN index for features: „the less finally value the better" were calculated from formula [1]:

$$SN_i = -10 \cdot \log\left(\frac{1}{n}\sum y_{ij}^2\right) \tag{1}$$

As the results of calculation of each parameters influence on surface roughness after roller burnishing, basing in presented in Tab. 1 experiment plan and formulae according to [1, 3], the following equations were obtained:

$$Y(A) = \frac{Y_3 + Y_4 + Y_6}{3} - \frac{Y_1 + Y_2 + Y_5}{3} = 1{,}958 - 0{,}767 = 1{,}191 \tag{2}$$

$$Y(B) = \frac{Y_3 + Y_5 + Y_6}{3} - \frac{Y_1 + Y_2 + Y_4}{3} = 1{,}046 - 1{,}679 = -0{,}633 \tag{3}$$

$$Y(C) = \frac{Y_4 + Y_5 + Y_6}{3} - \frac{Y_1 + Y_2 + Y_3}{3} = 1{,}519 - 1{,}206 = 0{,}313 \tag{4}$$

$$Y(D) = \frac{Y_2 + Y_5 + Y_6}{3} - \frac{Y_1 + Y_3 + Y_4}{3} = 0{,}702 - 2{,}023 = -1{,}321 \tag{5}$$

However the resistance of particular parameters on process disturbances for selected levels was as follows:

$$SN(A) = SN(+A) - SN(-A) = \frac{SN_3 + SN_4 + SN_6}{3} - \frac{SN_1 + SN_2 + SN_5}{3} = \\ = -17{,}511 - 8.330 = -25{,}841 \tag{6}$$

$$SN(B) = SN(+B) - SN(-B) = \frac{SN_3 + SN_5 + SN_6}{3} - \frac{SN_1 + SN_2 + SN_4}{3} = \\ = 0{,}639 - (-9{,}820) = 10.459 \tag{7}$$

$$SN(C) = SN(+C) - SN(-C) = \frac{SN_4 + SN_5 + SN_6}{3} - \frac{SN_1 + SN_2 + SN_3}{3} = \\ = -4{,}243 - (-4{,}938) = 0{,}695 \tag{8}$$

$$SN(D) = SN(+D) - SN(-D) = \frac{SN_2 + SN_5 + SN_6}{3} - \frac{SN_1 + SN_3 + SN_4}{3} = \\ = 9{,}490 - (-18{,}671) = -28.161 \tag{9}$$

Figure 1 shows graphical presentation of the results.

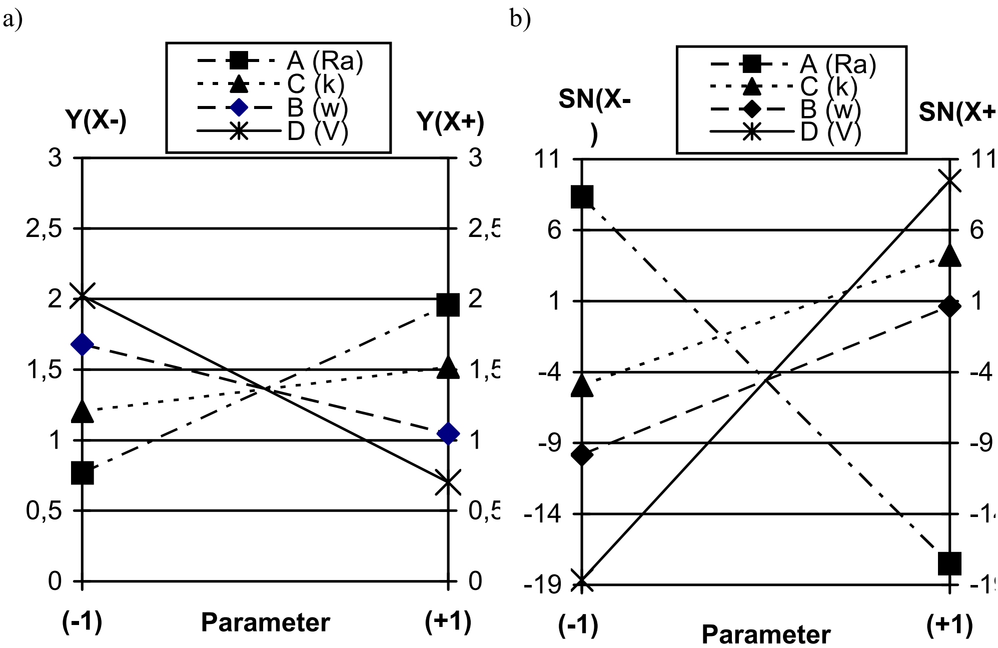

Fig. 1. The dependencies between surface roughness after roller burnishing and analysed parameters (a) and its resistance SN for process disturbances (b).

4 Conclusion

The following conclusions can be drawn:

- For tested change area of parameters burnishing velocity (V) and previous surface roughness (R_a) strongly effect surface roughness after roller burnishing. The smaller initial surface roughness the smaller roughness after roller burnishing. The higher burnishing velocity the smaller surface roughness height after roller burnishing. In this case, it is difficult to determine reason of this phenomenon
- The deeper depth of interference the smaller surface roughness height after roller burnishing.
- Substantial influence of deformation multiplicity on surface roughness height after roller burnishing was not observed.
- Previous surface roughness height and burnishing velocity show the least resistance for process disturbances

The conclusions obtained basing on carried out tests, relate only to presented technological conditions and cannot be the base general conclusions. But they can be the fundamentals for future tests of roller burnishing process taking into account the effect of other constructional-technological parameters (for example R, R/r) or burnished materials properties.

References

1. A. Hamrol, W. Mantura, *Zarządzanie jakością. Teoria i praktyka,* (PWN, Warszawa-Poznań, 2008)
2. A. Gazda, A. Pacana A., D. Malindžak, Przemysł Chemiczny, **6**, 980 (2013).
3. M. Korzyński, *Metodyka eksperymentu*, (WNT, Warszawa, 2006)
4. R. Ulewicz*, International Conference on the Path Forward for Wood Products: A Global Perspective* (Baton Rouge, 2016)
5. M. Korzyński, A. Pacana, Journal of Materials Processing Technology **210,** 1217 (2010).
6. S. Aysun, *Analysis and optimization of surface roughness in the ball burnishing process, using response surface methodology and desirability function, Advances in Engg.* (Software, 2011)
7. A. Pacana, W. Koszela, *Nagniatarka do bezkłowego krążkowania wałków, Materiały VII KNT Technologia obróbki przez nagniatanie* Bydgoszcz, 2000)
8. R. Wolniak, B. Skotnicka-Zasadzień, Metalurgija, **4**, 709 (2014)
9. H. Luo, J. Liu, L. Wang, Q. Zhong, The International Journal of Advanced Manufacturing Technology, **28**, 707 (2006)
10. N. Kumar, S. Anish, L. pal Singh, H. Tripathi, J. Liu, L. Wang, Q. Zhong, International Journal of Machining and Machinability of Materials*,* **18**(**1/2**),185 (2016)
11. P.R. Babu, K. Ankamma, K., T.S. Prasad, A.V.S. Raju, N.E. Prasad, International Journal of Engineering Research and Applications, **2**, 2,1139 (2012)
12. N.H. Loh, S.C. Tam, Precision Engg., **4**, 215 (1988)
13. R. Ulewicz, J. Selejdak, S. Borkowski, M. Jagusiak-Kocik, *Metal 2013, 22nd International Conference on Metallurgy And Materials (*Tanger Ltd, 2013)
14. M. Nowicka-Skowron, R. Ulewicz, *Metal 2015, 24TH International Conference on Metallurgy And Materials*, (Tanger Ltd, 2015)
15. A. Pacana, Production Engineering Archives, **16**, 28-31,(2017)
16. J. Pietraszek, A. Gądek-Moszczak, T. Torunski, Adv. Mat. Res.-Switz. **874**, 139 (2014)
17. N. Radek, J. Pietraszek, B. Antoszewski, Adv. Mat. Res.-Switz. **874**, 29 (2014)
18. J. Pietraszek, A. Szczotok, N. Radek, Arch. Metall. Mater. **62**, 235 (2017)
19. A. Dudek, B. Lisiecka. R. Ulewicz, Arch. Metall. Mater. **62**, 281-287 (2017)
20. T. Lipinski, A. Wach, *23rd International Conference on Metallurgy And Materials, 23rd International Conference on Metallurgy And Materials* (2014)