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THE EFFECT OF PARAMETERS BURNISHING ROLLING – PRESSURING PROCESS IN ASPECT TO TECHNOLOGICAL QUALITY SURFACE LAYER OF 316L STAINLESS STEEL

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Abstract

In the manufacturing of machine elements was important to technological quality products. In surface engineering one of the economic and ecological treatments used for technological properties were burnishing rolling – pressuring process. This is a surface plastic forming a local plastic deformation based on the overall impression given by smooth and hard tool. In production, engineering cylindrical outer surfaces (e.g. plugs propulsion shaft centrifugal pumps seawater) were finishing. You can therefore propose burnishing in exchange for abrasive machining.

The article presents the influence of parameters for burnishing rolling – pressuring process on the degree of relative strain hardening and surface roughness reduction ratio. Burnishing process carried out for 316L stainless steels. After the experimental study, it was determined that there was an increase in hardness and a decrease in roughness of the top outer cylindrical layer of stainless steel, which can be applied to the centrifugal pump shafts ship. Important question to determine in the article of the research was to receive appropriate technological quality. The burnishing due the technological and economic aspect in the production of machine parts in exchange for the abrasive processing can be used. After the experiments, it was found that the technical parameters are influenced by the hardness and the roughness of the outer cylindrical surfaces and the material ratio curve a convex shaped, which, taking into account the load capacity of the surface will be directly affected by its resistance to wear and corrosion of the surface layer.

Keywords: *burnishing process, hardness, roughness, surface layer, stainless steel*

1. Introduction to the issue of burnishing

The technological quality of the surface layer of the different machine elements interacts during the technological process and determines their performance characteristics. The burnishing rolling – pressuring process is a surface plastic forming. The aim of the burnishing is smoothing and strengthens the surface layer [1, 2, 4-9]. The finishing is aimed at pre-determined reduction of surface irregularities after treatment earlier to burnishing. The strengthening processing aim is producing specific changes in the physical properties of the material in the surface layer of the object, causing it to be resistant to operational factors such as fatigue, wear, corrosion and others. The dimension and surface finishing is aimed a predetermined increase in dimensional accuracy, whilst reducing surface roughness to the required value. To the project of the technological process of the production of machine parts, select the way of burnishing, machining conditions, the shape, and the number of elements tool. The selection of the burnishing circumstances depends on how the of using press elements into the surface being machined [3, 6, 10, 12].

In the case of elastic, press the tool to the product machining, the most important requirement burnishing value contact force. Definition of contact force is eventual by using a calculating and of experiment. It is confined primarily to determine the approximate value of burnishing force needed to complete deformation irregularities after earlier machining. After experimental research of the burnishing for the 316L stainless steels, have been determined that a significant effect on the hardness and the roughness surfaces, have the technological parameters: burnishing speed, feed rate, depth of disk burnishing tool and machining passes.

2. The experimental research methodology

The experimental research was made by burnishing rolling – pressuring process. The research laboratory were carried out for stainless steel 316L compliant to AISI (ASTM A 240-96) (X2CrNiMo17-12-2 according to the PN-EN 10088-1:2014-12) with the chemical composition is given in Tab. 1. The chemical composition of the samples was analysed using an optical emission spectrometry by SOLARIS-CCD PLUS. The cylindrical external shape were machining on using disk burnishing tool feed values a_n = 1.0 mm. This is the value of cross slide shift to the axis of the workpiece in two machining passes. Burnishing process by burnisher roller (BR01) and turning with insert TNMX 160408-WM carbide tipped 4015 on a universal centre lathe CDS 500x1000 is carried out. The turning parameters of machining process were selected on the basis of individual research and literature review [1, 3, 12]. The cutting parameters were used: feed rate f = 0.2 mm/rev, depth of cut a_p = 0.5 mm, cutting speed v_c = 100 m/min. The parameters were used during the burnishing: feed rate f_n = 0.2 mm/rev and burnishing speed v_n = 50-140 m/min, while lubrication and cooling was performed using machine oil. The turning by cutting tool and burnishing rolling – pressuring process (BRP) by burnisher roller is shown in Fig. 1.

Tab. 1. Chemical composition of steel stainless steels 316L

C [%]	Cr [%]	Ni [%]	Mo [%]	Mn [%]	Cu [%]	Si [%]	Co [%]	V [%]	S [%]	P [%]	Nb [%]	W [%]
0.025	16.517	9.548	2.123	1.003	0.578	0.409	0.216	0.092	0.025	0.022	0.030	0.022

The parameters of the burnishing rolling – pressuring process are shown in Tab. 2. The parameters of surface roughness measurements were performed to the principles contained in ISO standards. After the burnishing process were measured using a profilometer Hommel Tester T1000, with the measurement lengths of 4.8 mm and 0.8 mm for the elementary section. The samples surfaces before measuring were cleaned and degreased. A number of parameters of surface roughness after burnishing were determined, among other things; parameters were defined associated with the material ratio curve.

Afterwards measurements of the arithmetical mean deviation of the roughness profile were performed, that surface roughness reduction ratio was determined [2, 9]:

$$K_{Ra} = \frac{Ra_b}{Ra_a}, \tag{1}$$

where:
K_{Ra} – surface roughness reduction ratio,
Ra_b – the arithmetical mean deviation before burnishing ($Ra_b = 3.3\ \mu m$),
Ra_a – the arithmetical mean deviation after burnishing.

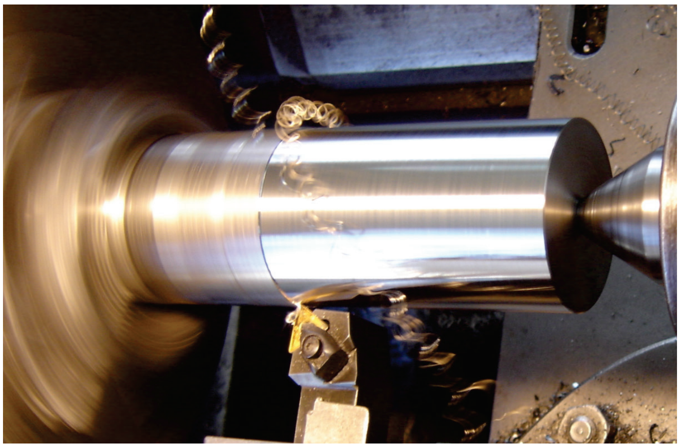
The hardness was measured at ambient temperature with a force 980.7 mN (100 gf) of ten seconds. The hardness was measured with the use of Vickers Hardness Tester model FM-800 type D by norm ISO/DIS 6507-2 (ASTM E-384). To estimate the effect of the parameters on microhardness on the surface layer, the degree of relative strain hardening in accordance with the following formula was determined [2, 9]:

$$S_u = \frac{HV_b - HV_a}{HV_a} \cdot 100\%, \tag{2}$$

where:

S_u – degree of relative strain hardening,
HV_b – microhardness before burnishing 233 HV0.1,
HV_a – microhardness after burnishing.

a)



b)

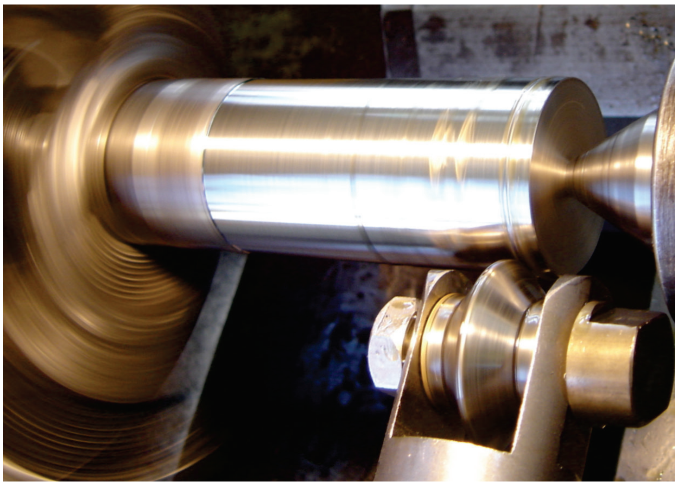


Fig. 1. The turning (a) and burnishing (b) for 316L stainless steel samples

The microstructure of stainless steel samples was observation of using Scanning Electron Microscopy EVO MA 15 and optical microscopy Axio Observer D1 MAT. The assessment of the deformation effect on the surface layer structure was carry out with optical microscope at 1000 × magnification.

3. The results of experimental research

The experimental research it was determined that the roughness is significantly affected by the technological parameters of the shafts burnishing process. The smaller values of arithmetical mean deviation of the surface roughness profile after burnishing can be obtained that using average burnishing speed. The values of the surface roughness profile parameters after burnishing process is presented in Tab. 2. On the Fig. 2 and 3 presents the relationship between the parameters of burnishing of stainless steel and the surface roughness reduction ratio and degree of relative strain hardening of the surface layer. When comparing the parameters related to the parameters material share curve shown in Tab. 2 and Fig. 4, it can be concluded that the most favourable distribution of the parameters of material share can be observed for disk burnishing tool feed a_n = 1 mm and feed f_n = 0.2 mm/rev and burnishing speed v_n = 70 m/min for machining passes i = 2.

Tab. 2. The parameters of the burnishing process and the example of measurements of the parameter of surface roughness and microhardness for the shaft with stainless steels 316L after burnishing for disk burnishing tool feed a_n = 1 mm and feed rate f_n = 0.2 mm/rev, for machining passes i = 2 for different values burnishing speed

v_n [m/min]	f_n [mm/rev]	a_n [mm]	Rz [µm]	Ra [µm]	Rk [µm]	Rpk [µm]	Rvk [µm]	K_{Ra} [-]	HV0.1	S_u [%]
140	0.2	1.0	5.52	0.70	2.24	1.65	2.87	4.7	427	83.3
100	0.2	1.0	5.43	0.57	1.09	1.18	2.44	5.7	437	87.6
70	0.2	1.0	4.84	0.53	0.99	0.87	1.55	6.3	447	91.9
50	0.2	1.0	4.43	0.51	0.89	0.85	1.53	6.4	455	95.3

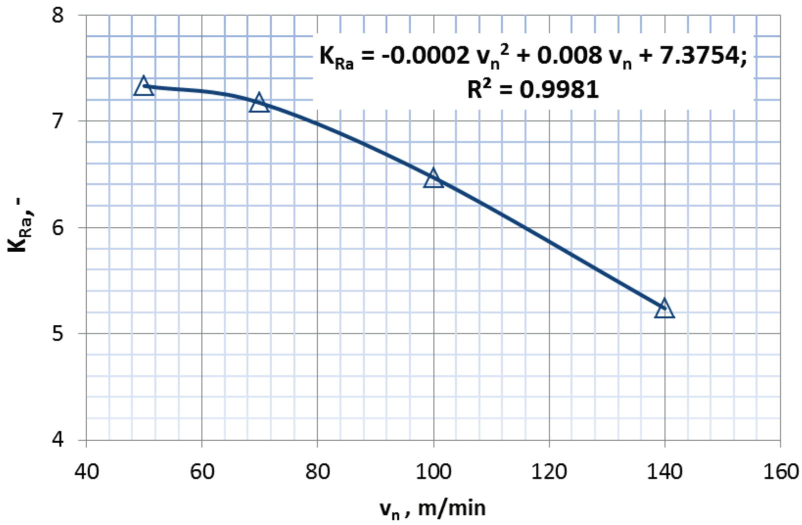


Fig. 2. The effect of the burnishing speed (v_n) on surface roughness reduction ratio (K_{Ra}) after burnishing rolling − pressuring process (BRP) for disk burnishing tool feed a_n= 1.0 mm and feed rate f_n = 0.2 mm/rev, for two machining passes

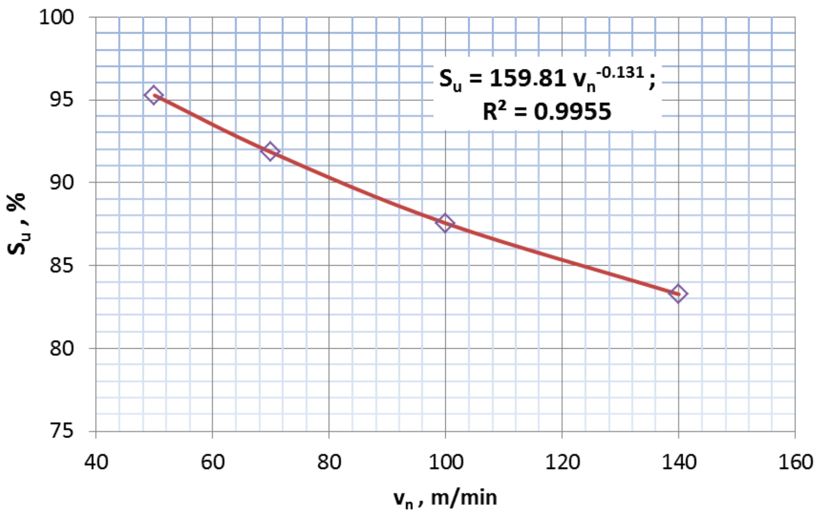


Fig. 3. The effect of the burnishing speed (v_n) on degree of relative strain hardening (S_u) after burnishing rolling − pressuring process (BRP) for disk burnishing tool feed a_n= 1.0 mm and feed rate f_n = 0.2 mm/rev, for two machining passes

The analysed of data and dependencies presented in Fig. 2-4 and in Tab. 2, it can be defined that to achieve a reduction in surface roughness and to increase the hardness of the surface layer after the burnishing of the stainless steels, for specified parameters, should be use v_n = 70 m/min, feed f_n = 0.2 mm/rev and disk burnishing tool feed a_n = 1.0 mm.

On the Fig. 5 is shown distribution microhardness on the distance from burnishing surface for the different values burnishing speed and two machining passes. The supreme microhardness values can be found at a depth of to about 500 μm from the burnishing surface for two machining passes. From a depth of 1500 μm, it can be seen that hardness of the material is similar as in the core.

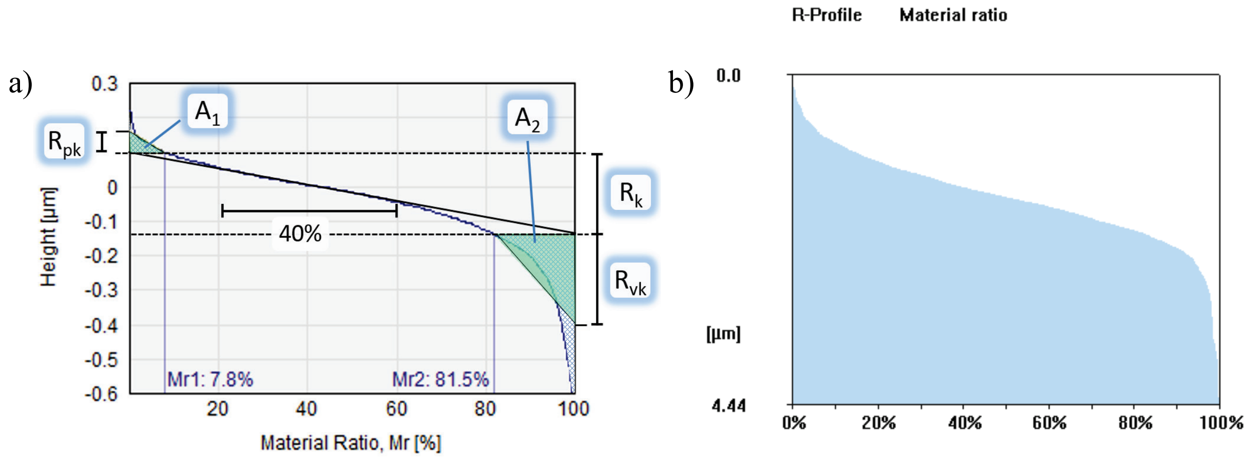


Fig. 4. The material ratio curve surface roughness: theoretical (a) (where: Rk − the core roughness depth; Rpk − the reduced peak height; Rvk − the reduced valley depth) [2, 4, 11] and experimental (b) (Ra = 0.53 μm; Rk = 0.99 μm; Rpk = 0.87 μm; Rvk = 1.55 μm) for the samples after burnishing rolling − pressuring process (BRP) for stainless steel 316L for the burnishing speed v_n = 70 m/min for disk burnishing tool feed a_n = 1 mm and feed rate f_n = 0.2 mm/rev, for two machining passes

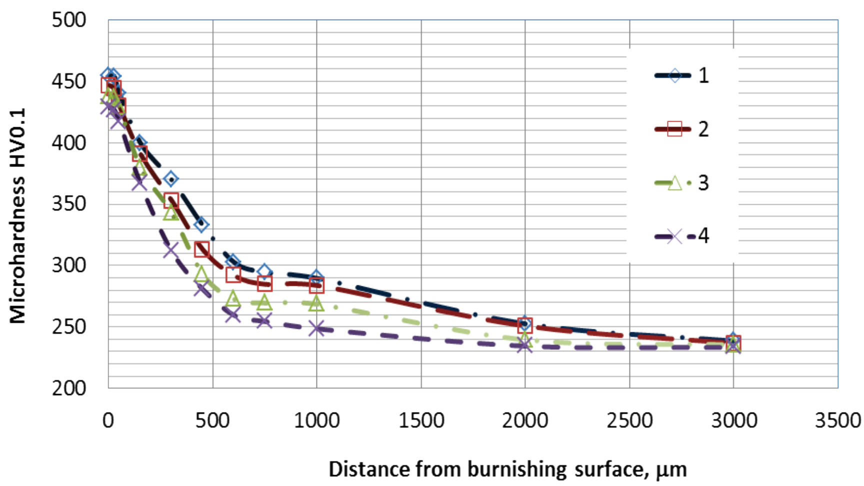


Fig. 5. The distance from burnishing surface on microhardness for the burnishing speed: 1 − v_n = 50 m/min, 2 − v_n = 70 m/min, 3 − v_n = 100 m/min, 4 − v_n = 140 m/min, for disk burnishing tool feed a_n = 1 mm and feed rate f_n = 0.2 mm/rev, for two machining passes

On the Fig. 6 is shown the microstructure after burnishing of the shafts for stainless steel 316L for the burnishing speed v_n = 70 m/min for disk burnishing tool feed a_n = 1 mm and feed rate f_n = 0.2 mm/rev, for two machining passes in the cross-section. Upon observation of the microstructure, it could be concluded that the structure changes are of a minor depth, of several micrometres.

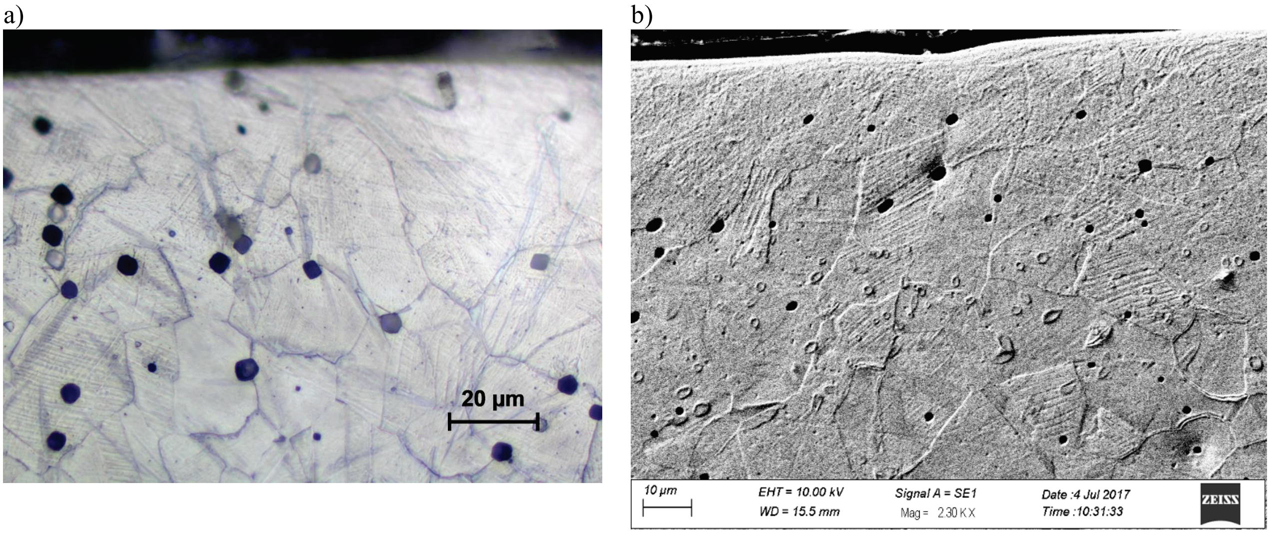


Fig. 6. The microstructure of the shafts after burnishing rolling − pressuring process (BRP) for stainless steel 316L for the burnishing speed v_n = 70 m/min for disk burnishing tool feed a_n = 1 mm and feed rate f_n = 0.2 mm/rev, for two machining passes, external part in the cross-section by microscopy: a) Axio Observer D1 MAT and b) EVO MA 15

4. Summary and conclusions

In the production of metal used in components of machines, it is essential to be assured required technological quality of the surface layer. The surface engineering one of ecological and economical treatments used to form mechanical and technological properties of the surface layer is burnished. In the article were presented the influence of technological parameters of burnishing on the degree of relative strengthening and the coefficient of roughness reduction. The burnishing was carried out on cylindrical samples made of 316L stainless steel. Upon completion of the experimental studies we found that there is an increase hardness and reduce the surface roughness curve and the share of material has a convex shape, which may affect the corrosion resistance and resistance to abrasive wear of the surface layer.

After experimental was completed, the relationship between the parameters of burnishing process on the degree of relative strain hardening and surface roughness reduction ratio was determined. The maximum values of the surface roughness reduction ratio and the degree of relative strain hardening for two machining passes can be obtained for burnishing speed v_n = 70 m/min, feed rate f_n = 0.2 mm/rev and disk burnishing tool feed a_n = 1.0 mm. Strengthening of the surface layer for the samples subjected to burnishing obtains the largest values in the distance from the surface to 500 μm for two machining passes. Then the carried out experimental, it can be determined that to get the greatest degree of relative strengthening at the lowest surface roughness for the assumptions work, it would be necessary to use a low burnishing speed and small feed rate for two machining passes.

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