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THE BURNISHING PROCESS OF THE STAINLESS STEEL IN ASPECT OF THE REDUCTION ROUGHNESS AND SURFACE HARDENING

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Abstract

In the article were presented influence of technological parameters of burnishing process on the degree of hardness and reduction roughness. Burnishing process carried out for stainless steels X2CrNiMo17-12-2. The experimental research were obtained in the surface layer increase in hardness 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. The experimental research by application of the burnishing rolling – pressuring process (BRP) method were made in the Laboratory of Production Engineering at the Department of Marine Maintenance at the Faculty of Marine Engineering at the Gdynia Maritime University. After the studies it was found that the hardness of the surface layer and the roughness of the shaft necks an important influenced by technological parameters of processing (burnishing speed, feed and depth of burnishing). The objective of applying burnishing process may be, for example, the need to increase surface smoothness and dimensional accuracy of part. To achieve the objectives strengthen and smooth of burnishing stainless steel should be used the one pass burnisher roller and feed f_n = 0.2 mm/rev and disk burnishing tool feed a_n = 1.0 mm and burnishing speed v_n = 70 m/min.

Keywords: *burnishing rolling – pressuring process (BRP), surface roughness reduction ratio, degree of relative strain hardening, stainless steel*

1. Introduction

The aim of applying burnishing particular treatment method may be, for example, the need to increase surface smoothness and dimensional accuracy of element [1, 3, 4, 7, 9, 12], as well as economic regards, the increase resistance to fatigue and corrosion resistance [6, 12]. The depth of plastic deformation and the value of hardening and machining accuracy are the main differences in machining results for each burnishing method. The burnish include: reinforcement treatment – for which it is important to achieve the desired changes in the physical properties of the material, which among other reduce abrasive wear and increase hardness and fatigue strength; smoothing – which aims at reducing the roughness and roughness of the surface. Dimensional smoothing treatment – through which accurate dimensional accuracy is achieved, combined with obtaining of low surface roughness [5, 7, 10, 12, 13].

During designing of technological process of manufacturing or regenerating machine components, the method of burnishing, the machining conditions, the shape and number of burners should be selected. The choice of static pressure conditions during burnishing process is dependent on how the pressure components are applied to the workpiece surface, which can be elastic or rigid. The reliability of working machine and equipment is very important in the engineering, power, metallurgical or marine industries. For example, on a ship during a cruise, are made repairs of individual components of the ship's machinery. Often are regenerated external cylindrical surfaces (e.g. shaft seals of seawater pumps), for this purpose can be proposed burnishing rolling – pressuring process (BRP) can be proposed as a finishing treatment, which enables to obtain the technological quality requirements of the products surface layer.

The selection of burnishing conditions is based on approximate calculations of forces and unitary pressures, experimental results of materials with similar properties, universal nomograms and specialist norms [4, 7, 9, 12]. For cases where there are insufficient certain dependencies and nomograms and for burnishing with simultaneous cutting, the selection of conditions should be made on the basis of preliminary tests [5, 9, 12, 13].

The technological process resulting in low surface roughness should be realized with application of as much pressure as possible on the surface of the treated element, while the speed of the burnishing and the feed should be low. In contrast, burnishing, which is intended to increase the strength properties of the surface layer of the machine parts, inter alia by increasing the hardness, should be characterized by the use of high shear force for low feed and burnishing speed. The value of the clamping force should be optimal for each type of burnishing treatment. Too high a value can lead to peeling, which is accompanied by rapid increase in roughness. On the other hand, it is to low value relative to the optimum strength will not provide sufficiently low roughness, because it will not completely deform the remaining inequalities after previous treatments. Too much clamping pressure of the burnisher can adversely affect the quality of the treated surface due to the possibility of appearance of surface defects and the presence of stress corrosion [4, 12]. Corrosion resistance of burnished elements depends on the degree of deformation and surface smoothing. It is therefore important correctly to determine the technological parameters of the burn treatment depending on whether it is the smoothness or reinforcement treating.

After initial preliminary experiments, of burnishing of the stainless steel, have been determined that a significant effect on the hardness of the top layer and the roughness of the outer cylindrical surfaces, have the machining parameters (speed, feed and depth of burnishing).

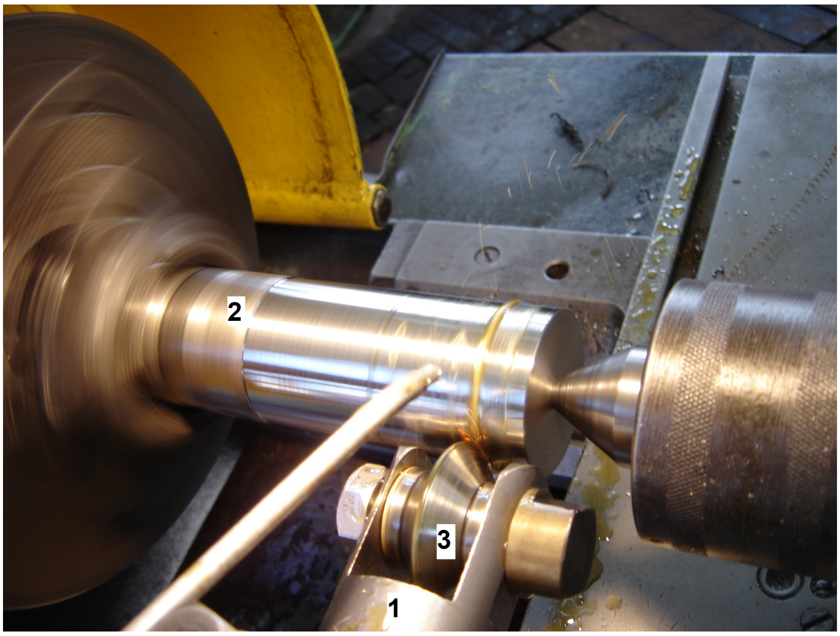

Fig. 1. The burnishing rolling – pressuring process (BRP): 1 – burnisher roller (BR–01), 2 – outer cylindrical surfaces, 3 – disk burnishing tool

2. The methodology of experimental research

Experimental investigations were made for the stainless steels X2CrNiMo17-12-2, with the chemical composition is given in Tab. 1. Outer cylindrical surfaces were prepared for the burnishing process by machining on a universal lathe CDS 500x1000. The technological parameters were selected on the basis of own research and literature review [2, 8, 11, 14]. The following 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. During the process there was no cooling used, dry work was done. Longitudinal machining was made using lathe equipped with inserts TNMX 160408 – WM DTGNR 2020K 16 carbide tipped 4015 [14].

The burnishing with rigid pressing was realized using a burnisher roller (BR-01) on a universal lathe, CDS 500x1000 by exerting a holdfast force on the slider for longitudinal feed. The BR-01 had a burnishing element in the form of a disc with a diameter of ϕ50 mm and a rounding radius of a working part of 3 mm with a hardness of 870 HV30. The following technological parameters were used during the burnishing treatment: feed f_n = 0.2-1.2 mm/rev; disk burnishing tool feed a_n = 0.5-1.0 mm; burnishing speed v_n = 50-140 m/min, number of machining pass i = 1. To the process, the machine oil was used for lubrication and cooling.

Tab. 1. Chemical composition of steel stainless steels X2CrNiMo17-12-2

C [%]	Cr [%]	Ni [%]	Mo [%]	Cu [%]	Mn [%]	Si [%]	S [%]	P [%]
0.024	16.5	9.5	2.12	0.57	0.99	0.41	0.025	0.022

The measurements were performed to the principles contained in ISO standards, a number of parameters of surface roughness after burnishing were determined; among other things, parameters were defined associated with the material ratio curve. Before measuring, the sample surfaces were cleaned and degreased. After measurements of the arithmetical mean deviation of the roughness profile after burnishing (*Ra*) were performed, that surface roughness reduction ratio (K_{Ra}) [5, 12] was determined. The arithmetical mean deviation before burnishing of the value was equal to 3.3 µm. A number of parameters of surface roughness after burnishing were determined, among other things, the arithmetical mean deviation (*Ra*).

The microhardness was measured with the use of Vickers Hardness Tester FM-800 by norm PN-EN ISO 6507-1:1999. The load of 0.980 N was applied for ten seconds at the ambient temperature. To assess the effect of the technological parameters on microhardness on the surface layer, the degree of relative strain hardening (S_u) [4, 12], where microhardness before burnishing 233 HV0.1 was determined.

3. The results of experimental research

The experimental study by application of the burnishing rolling – pressuring process (BRP) were made in the Laboratory of Production Engineering at the Department of Marine Maintenance at the Faculty of Marine Engineering at the Gdynia Maritime University. The following parameters of burnishing were determined at constant burnishing speed v_n = 70 m/min and variable feeds f_n = 0.2-1.2 mm/rev (Tab. 2) and constant feed f_n = 0.2 mm/rev. Variable burnishing speed v_n = 50-140 m/min (Tab. 3) using disk burnishing tool feed of a_n = 0.5-1.0 mm and one of machining pass.

Tab. 2. The example of measurements of the parameter of surface roughness and microhardness for the shaft with stainless steels X2CrNiMo17-12-2 after burnishing for the speed v_n = 70 m/min for different values of feed and disk burnishing tool feed

v_n [m/min]	f_n [mm/rev]	a_n [mm]	*Ra* [µm]	K_{Ra} [–]	HV0.1	S_u [%]
70	**0.2**	**1.0**	**0.45**	**7.3**	**289**	**24.3**
70	0.6	1.0	0.63	5.3	279	19.7
70	0.9	1.0	1.55	2.2	270	15.8
70	1.2	1.0	1.66	1.9	247	6.0
70	0.2	0.5	0.48	6.8	285	22.3
70	0.6	0.5	0.65	5.1	273	17.2
70	0.9	0.5	1.25	2.6	267	14.5
70	1.2	0.5	1.35	2.4	245	5.1

Tab. 3. The example of measurements of the parameter of surface roughness and microhardness for the shaft with stainless steels X2CrNiMo17-12-2 after burnishing for the feed f_n = 0.2 mm/rev for different values burnishing speed of and disk burnishing tool feed

v_n [m/min]	f_n [mm/rev]	a_n [mm]	Ra [μm]	K_{Ra} [–]	HV0.1	S_u [%]
140	0.2	1.0	0.63	5.2	255	9.4
100	0.2	1.0	0.51	6.5	279	19.7
70	**0.2**	**1.0**	**0.45**	**7.3**	**289**	**24.3**
50	0.2	1.0	0.50	6.6	293	25.7
140	0.2	0.5	0.56	5.9	253	8.6
100	0.2	0.5	0.49	6.7	277	18.9
70	0.2	0.5	0.48	6.8	285	22.3
50	0.2	0.5	0.53	6.2	286	22.7

Figures 2-5 present the relationship between the parameters of burnishing of stainless steel (burnishing speed – v_n, feed rate – f_n, disk burnishing tool feed – a_n) and the surface roughness reduction ratio (K_{Ra}) and degree of relative strain hardening of the surface layer (S_u).

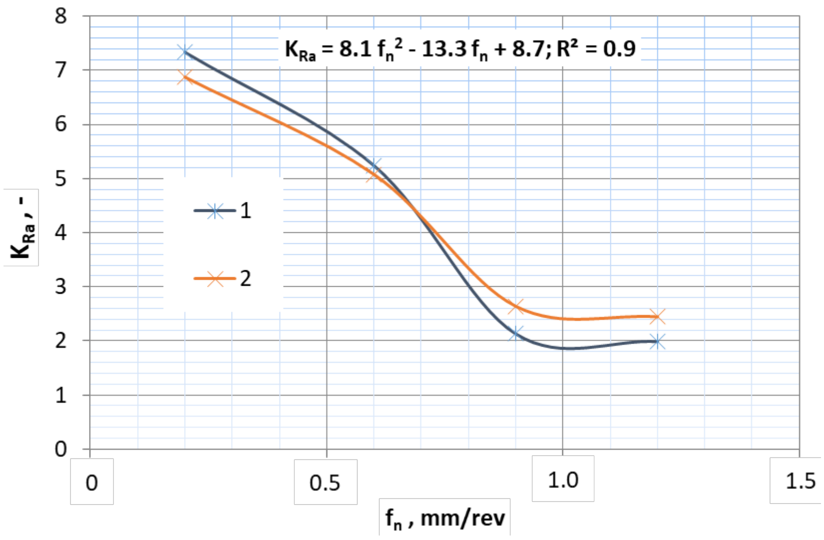

Fig. 2. The influence of the feed f_n on surface roughness reduction ratio (K_{Ra}) after burnishing rolling – pressuring process (BRP) for disk burnishing tool feed: 1 – a_n = 1.0 mm and 2 – a_n = 0.5 mm

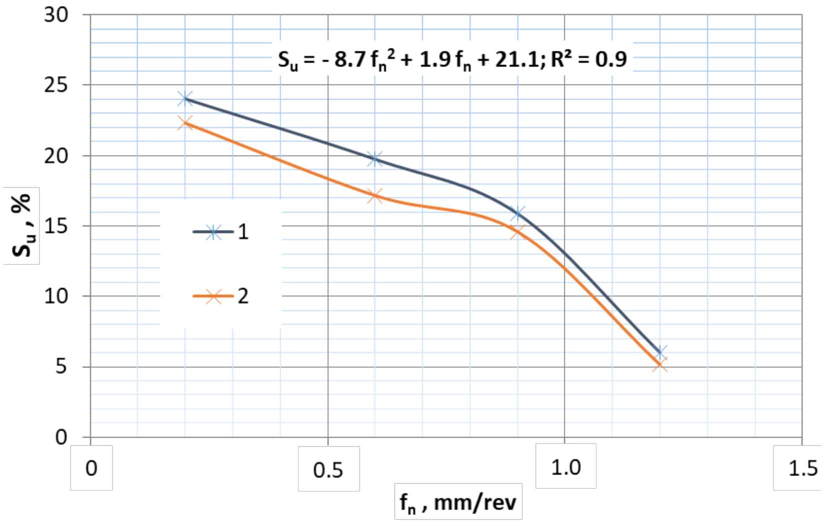

Fig. 3. The influence of the feed f_n on degree of relative strain hardening (S_u) after burnishing rolling – pressuring process (BRP) for disk burnishing tool feed: 1 – a_n = 1.0 mm and 2 – a_n = 0.5 mm

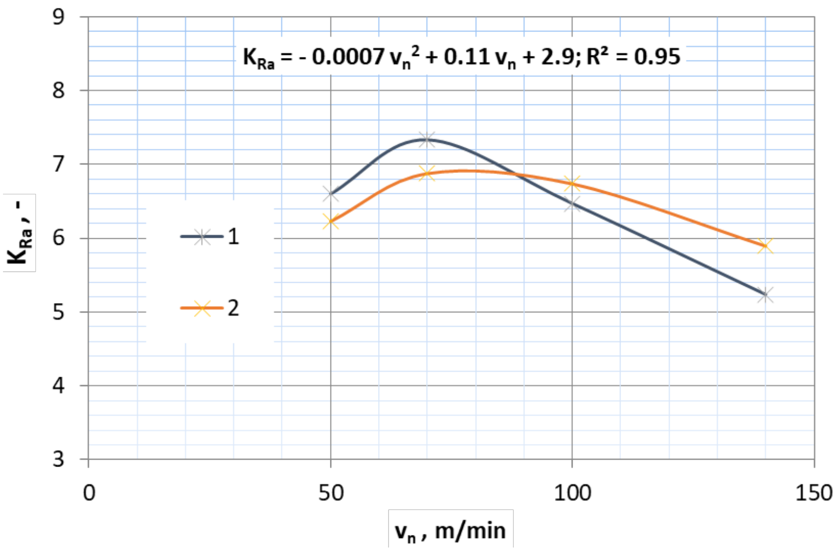

Fig. 4. The influence of the burnishing speed v_n on surface roughness reduction ratio (K_{Ra}) after burnishing rolling – pressuring process (BRP) for disk burnishing tool feed: 1 – a_n = 1.0 mm and 2 – a_n = 0.5 mm

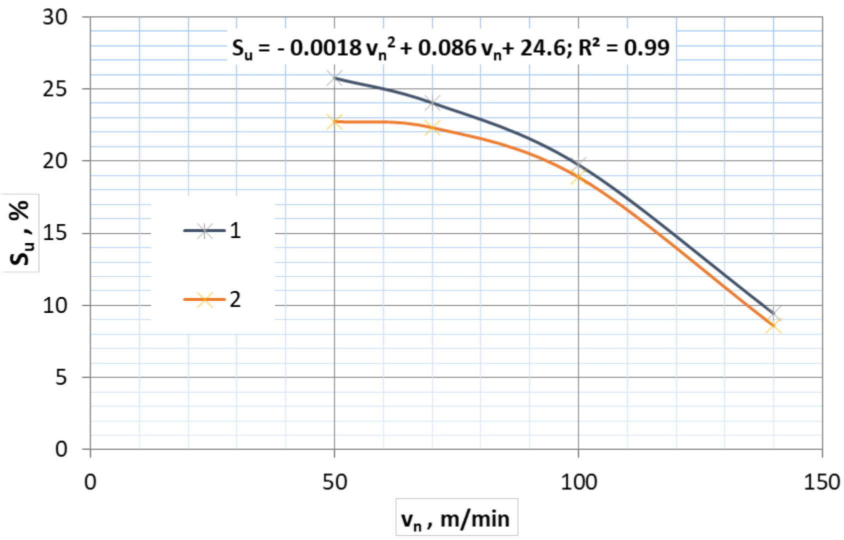

Fig. 5. The influence of the burnishing speed v_n on degree of relative strain hardening (S_u) after burnishing rolling – pressuring process (BRP) for disk burnishing tool feed: 1 – a_n = 1.0 mm and 2 – a_n = 0.5 mm

After experimental tests, the correlation between the burnishing rate and the surface roughness index (Fig. 2) and the degree of relative strain hardening (Fig. 3) were determined at the set parameters of the burnishing of the outer cylindrical surface. After burnishing, the relationship between the burnish rate and the surface roughness (Fig. 4) and the degree of relative strain hardening (Fig. 5) was developed.

According to the data shown in Fig. 2 can be stated that the value of the surface roughness reduction (K_{Ra}) decreases as the feed rate of the burnishing increases. The smallest values of the arithmetic mean of the ordinates of surface roughness after burnishing and thus the maximum values of the surface roughness decrease for low values of feed rates.

On the base of the analysis of results in Fig. 3, it can be concluded that, as the burnish rate increases, the degree (S_u) is lower. On the other hand, for the smaller feed rate values and for the larger values of the depth of the depth of burnishing, the relative strength of the surface layer is maximized.

Figure 4 shows the effect of the burnish rate on the surface roughness reduction index. It can be seen that increasing the burnishing speed values initially results in an increase in the value of the

K_{Ra} index and thus decreasing the roughness of the surface. The maximum values for this indicator are for a burnishing speed of v_n = 70 m/min. Further increasing the speed of burnishing results in a deterioration of the surface roughness.

According to data shown in Fig. 5 can be stated that with the increase in velocity, the degree of relative strain hardening (S_u) is lower. In addition, for the lower speed values and higher values of the depth of the burnisher depth, the relative strength of the surface layer gets the maximum value.

The analysis of data and dependencies presented in Fig. 2 to 5, it can be stated that to achieve a reduction in surface roughness and to increase the hardness of the surface layer after the treatment of the stainless steels X2CrNiMo17-12-2, for specified technological 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.

4. Summary and conclusions

After the experimental study of the burnishing rolling – pressuring process of the stainless steels X2CrNiMo17-12-2, it was stated that:

- there is a relationship between the feed, the burnishing speed, the surface roughness reduction ratio and the degree of relative strengthening by cold working,
- with the feed rate and burnishing speed increase, decreases the relative strength of the surface layer and the surface roughness factor,
- the maximum values of the surface roughness reduction ratio K_{Ra} = 7.3 and the degree of relative strain hardening S_u = 24.3% were obtained for v_n = 70 m/min, f_n = 0.2 mm/rev and a_n = 1.0 mm.

The lower feed rates and lower burnishing rates at higher infraction rates for the specified test range by using, the maximum relative strength of the surface layer as well as the maximum surface roughness ratio values can be obtained. The burnishing rolling – pressuring process (BRP) of the stainless steel to simultaneously achieve smoothing and reinforcing purposes should be carried out at the recommended parameters: disk burnishing tool feed a_n = 1.0 mm; feed rate f_n = 0.2 mm/rev; burnishing speed v_n = 70 m/min for the one pass of the burnisher roller (BR–01).

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