ESTIMATION OF THE INFLUENCE OF BURNISHING PROCESS ON STEEL X5CrNi1810 INTERNAL STRESSES

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Abstract

Angular momentum pumps are frequently applied on board ships. As the pumps are working in hard conditions they are made from materials resistant to cavitation wear and electrochemical corrosion. The most popular damage of pump shaft is neck wear in place where seals are mounted.

Burnishing, as modern finish plastic tooling method, makes it possible to get high technological quality of elements. The proposed process of burnishing shaft pins is designed to increase the service life of marine seawater pump shaft installations, which should enhance the economic effect.

Thanks to its numerous advantages burnishing was proposed to angular momentum pumps shafts tooling instead of finish machining (finish turning, grinding, lapping). The goal was to estimate optimal burnishing parameters which enable receiving biggest strengthening and lowest roughness factor of angular momentum pumps shafts. The tool used was one–roll burnishing tool SRMD type produced by Yamato. The aim of this study was to determine the internal stresses occurring in the subsurface layer after machining carried out, and after burnishing the surface of marine pump shaft pins made of X5CrNi1810 stainless steel.

Keywords: *burnishing, surface layers, stainless steel, angular momentum pump, internal stress*

1. Introduction

Angular momentum pumps have been widely used in marine engine rooms. They are applied in cooling systems for medium and high power engines, in boilers feed systems as well as in bilge, ballast and fire-fighting installations. Pump shafts working in sea water environment, are subjected to wear corrosion, fretting corrosion and erosion corrosion due to difficult service conditions. The application of an expensive material does not prevent material service damages which include: cracks, plastic deformations, excessive wear of pins where the rotor seals are mounted and where throttles are sealed, corrosion wear and splineways knock outs.

In service experience, the excessive wear of pins has been observed which can lead to the decrease of pins diameter and exceeding the recommended shape deviations [9].

The technology utilized in the production process has a considerable influence on the durability and reliability of machine parts. The final formation of surface layer, that is the dimensions and service properties, is achieved during finish treatment of a given element [1, 2]. The burnishing process, proposed here, aims at the achievement of suitable properties of surface layer, which should have a vital influence on the improvement of service life of marine pump pins in sea water installations. The review of literature pointed out three basic purposes of burnishing application in machine parts production process [3, 4]:

- smoothness tooling,
- strengthening tooling,
- dimension-smoothness tooling.

Burnishing technology can be used in machine production plants. It allows eliminating traditional finish machining such as: lathing, grinding, super finishing, honing and polishing. Therefore the final formation of dimensions and service properties by means of burnishing becomes a chipless and dustless treatment which qualifies burnishing for ecological treatment method [5]. In industrial environment this process is carried out on universal machine tools as well as on CNC but belongs to plastic tooling. Burnishing process enables surface working at high dimensional precision (accuracy class 7 and 6) which makes it possible to achieve many advantages which comprise:

- ability to achieve high smoothness (Ra = 0.32-0.04 μm) of the surface and high bearing surface roughness profile (90%),
- increasing the surface hardness,
- increasing resistance to fatigue (both surface and volumetric),
- increasing resistance to abrasive and mashing wear,
- lack of abrasive grain, chips, sharp and hard built-up edge fragments on burnished surface,
- possibility of using burnish tools on universal lathes (the concept of one stand working),
- eliminating or limiting the time consuming operations such as: honing, lapping, grinding and polishing,
- ability to eliminate heat treatment in specific cases,
- high process efficiency (one working transition of a tool) and reduction of production costs,
- high durability of burnishes,
- the expenses reducing related to machine parts of production.

The main limitation of burnishing is the material condition. Burnished objects must be made of materials enabling their tooling at ambient temperature, and in case of steel burnishing tools- they must have a limited hardness. The above mentioned criteria have different meanings for particular burnishing methods. Other limitation results from OUPN system (working tool, fixture, object, tool) and its rigidity which should be the highest as it determines the measurement accuracy of the object tooled.

Numerous scientific centres all over the world deal with burnishing treatment and its impact on the surface layer. Research programmes usually cover issues related to burnishing of cast iron [6], some heat resisting alloys, stainless steel, copper alloys and aluminium [8], titanium and its alloys [7], galvanic, diffusive and padded coatings as well as parts produced by sintering metal powders.

Within the research the optimization of burnishing technological parameters was conducted for the hardness and stereometric parameters of angular momentum pumps shaft pins. Therefore burnishing should be performed on account of the minimalization of R_a surface roughness factor as well as maximalization of S_u surface layer relative hardness degree.

The aim of the paper was to define internal stresses occurring in subsurface layer after machining that is finish lathing and after burnishing of angular momentum pumps shaft pins made of X5CrNi1810 stainless steel.

2. Samples preparation

The rollers of X5CrNi1810 stainless steel ϕ 26 mm in diameter were preliminarily machined. The process of turning was carried out on TUC 40 lathe by a cutting tool with WNMG 080408 WF removable plates by Sandvik Coromant (Fig. 1). Owing to appropriate geometry of a corner the Wiper plates ensure high efficiency of finish lathing. Possibility of applying two times more feed does not change the quality of the surface obtained in relation to traditional plates. During the process of lathing the following machining parameters were applied: machining speed V_c = 112 m/min, feed f = 0.27 mm/rev, machining depth a_p = 0.5 mm.

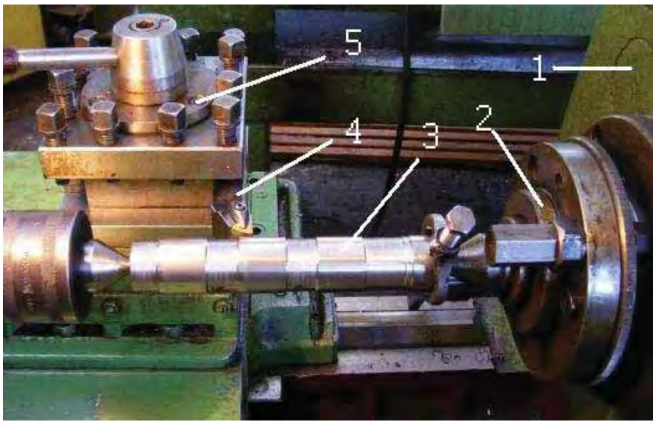

Fig. 1. The view of working assembly (machine tool, fixture, object, tool): 1 - TUC 40 lathe, 2 - catch plate, 3 - machined object, 4 - turning tool, 5 - tool post

The process of burnishing was conducted by SRMD one roll burnish by Yamato (Fig. 2) which is characterized by the parallelism of the working part axis to the machined roll axis, contrary to the common burnishes. Shaft pins made of X5CrNi1810 stainless steel of the diameter ϕ 25 mm were being burnished. During technological process optimized burnishing parameters were used thus enabling the achievement of the highest surface layer relative hardness degree and the reduction of surface roughness of marine angular momentum pumps shafts pins. The multi-criteria optimization [11] that was carried out by min-max method showed that considering the minimum surface roughness and the maximum surface hardness degree, burnishing should be conducted at the technological parameters included in Tab. 1.

Fig. 2. Burnishing tool

Tab. 1. Technological parameters of burnishing process

Parameter		Values
Burnishing force - F	[kN]	1.1
Feed - f	[mm/rev]	0.13
Burnishing speed - V_n	[m/min]	35

3. Research methodology

The hardness measurement was taken by Vickers method by means of WMP tool at thrust force amounting to 50 N. On the basis of the results achieved the degree of S_u surface layer relative hardness was determined:

$$S_u = \frac{HV_2 - HV_1}{HV_1} \cdot 100\%, \tag{1}$$

where:
S_u - degree of surface layer relative hardness,
HV_1 - material hardness before burnishing,
HV_2 - material hardness after surface plastic treatment.

Micro hardness measurements were taken by Vickers micro hardness tester H type mounted on Vertival microscope frame in compliance with the PN-ISO 6507-3 standard.

Microscope tests of cross sections of the pins examined were executed by (SEM) Philips XL30 scanning electron microscope.

The measurements of internal stresses were taken on a sample after finish lathing (T roll) and after burnishing operation (N roll). The measurements were taken on each element in five points 10 mm distant from each other (P0- a point in the centre of the roll, and the remaining ones P10, P20, P_10, and P_20 symmetrically distant from P0). The stresses were calculated based on $\sin^2\Psi$ X-ray method.

Diffraction measurements were taken on X-ray diffractometer by Bruker D8 Discover working in Bragg – Brentano geometry on point beam 1.5 mm in diameter with PSD VANTEC position sensitive detector by Bruker. The Cr Kα radiation was used with the wave length of λ=0.228973 nm. The records conditions were as follows: voltage - 40 kV, current - 40 mA, step $\Delta 2\Theta$ 0.03, and the measuring time of one measuring point - 400s (165 points for one element). Stresses analysis was made on a peak in an angular range of 2Θ 125.1-132.8.

4. Research results

The values of S_u coefficients defining the degree of surface layer relative hardness were changing according to burnishing parameters applied and fluctuated within 1% to 18%. The statistic analysis of burnishing process measurements results showed that burnishing speed has the greatest influence on S_u hardness coefficient and with its increase the decrease of the material relative hardness degree takes place. The burnishing force has a lower influence on S_u coefficient but with its increase the material surface hardness occurs. The feed has the lowest influence on the value of S_u surface layer relative hardness degree and it is statistically irrelevant. Detailed analysis of multiple regression is shown in the article nr.10.Whereas the final values of (BETA) standardized regression coefficients , (b) coefficients and significance levels (p level) of the multiple regression analysis that was carried out ,not taking feed into account, are included in Tab. 2. The remaining coefficients take constant values and are respectively: correlation coefficient $R = 0.81$, determination coefficient $R^2 = 0.65$, $F(2.45) = 42.175$, $p<.00000$ and estimation error: 2.42. The equation obtained for multiple regression of S_u variable is presented in Tab. 2.

Tab. 2. The results of S_u parameter statistic analysis for variables presented in Tab. 3 without taking the feed into account

	BETA	B	p level
Free term		12.05	0.00
Burnishing speed - V_n	-0.79	-0.11	0.00
Burnishing force - F	0.18	0.004	0.04
Multiple regression equation: $S_u = 0.004F - 0.11V_n + 12.05$			

Micro hardness tests were conducted in order to determine the thickness of a surface layer draft. For this examination samples after finish lathing and after burnishing were used. Micro hardness measurements that were taken, did not show any significant micro hardness changes. The examinations were taken on metallographic sections according to PN in transverse section of the pins and additionally on specifically prepared and bevelled sample surface. On the basis of the measurements taken, it was not possible to define the texture change of a draft, and that is why further factographic tests were conducted.

Figure 3 presents obtained values for surface layer relative hardness degree for pins burnished at burnishing speed – 35 m/min.

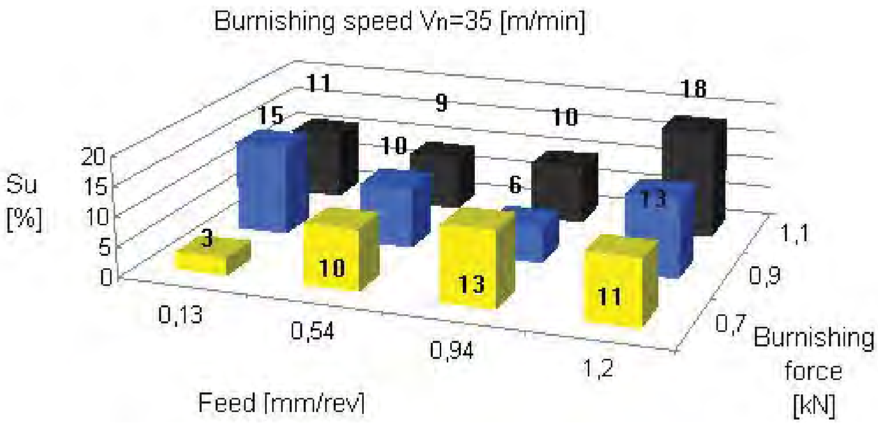

Fig. 3. Obtained S_u values for burnishing speed V_n = 35 m/min

Factographic research of the samples surface cross section, after preliminary lathing and after performing burnishing, in which the material surface layer hardness after treatment was 18% , is shown in Fig. 4. The analysis of factographic research results did not show any crucial changes of the surface layer draft texture. The measurements taken and the micrometric change of pins diameter after burnishing were related solely to the plastic deformation of surface roughness peaks. Surface smoothing was also observed after burnishing.

a) b)

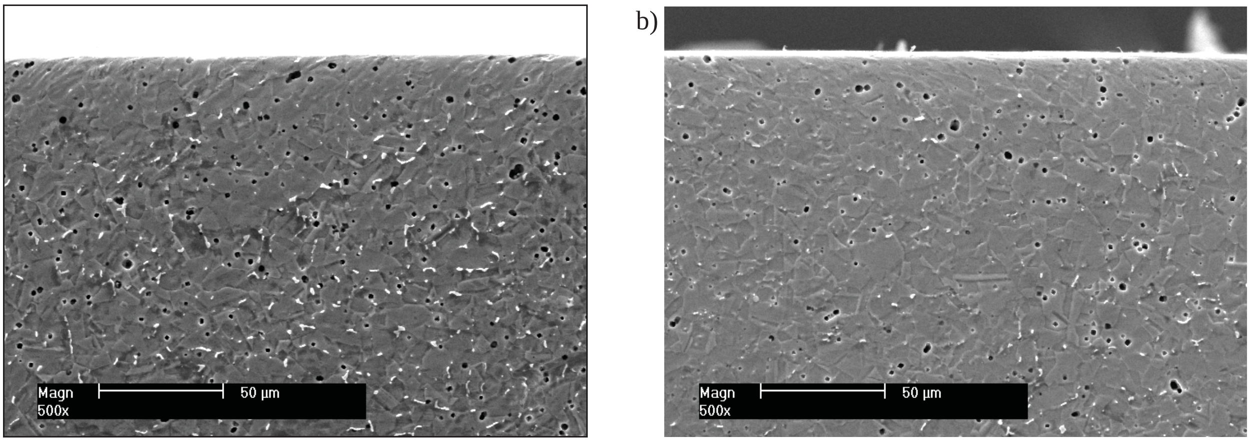

Fig. 4.View of sample surface section a) before burnishing b) after burnishing

In order to define structural changes in subsurface layer, the examination of internal stresses was carried out. The research results of internal stresses measurements are shown in Tab. 3. Summing up the results obtained, it must be stated that for the marine pump shaft pin that was subjected to stresses analysis after burnishing and after lathing and burnishing, the state of internal stresses at the depth of about 5µm kept the same level - the whole length of the element. Tensile stresses were observed in the element lathed but compressive stresses in the element burnished. The comparative results in Tab. 3 were given for σ_1 and σ_2 values calculated from stresses tensor at the assumption of flat stresses state $\sigma_{33} = 0$.

Tab. 3. The results of internal stresses measurements in sub surface layer.

Measuring point	T Roll		N Roll	
	σ_1	σ_2	σ_1	σ_2
P20	150 +/- 19	390 +/- 22	-131 +/- 23	-463 +/- 34
P10	207 +/- 24	371 +/- 27	-127 +/- 14	-461 +/- 21
P0	244 +/- 37	336 +/- 14	-120 +/- 27	-492 +/- 34
P_10	222 +/- 27	362 +/- 19	-127 +/- 19	-494 +/- 25
P_20	253 +/- 21	397 +/- 25	-122 +/- 31	-479 +/- 29

5. Results

The process of burnishing steel used for marine pumps shaft pins in sea water installations by means of a burnishing tool by Yamato makes it possible to achieve suitable technological quality of machine elements surface. Further research will determine the influence of burnishing on the improvement of service properties which include: the examinations of electrochemical corrosion, abrasive wear and contact fatigue. The internal stresses examinations results keeping the same level after lathing and burnishing as well as the stresses direction change from tensile to compressive stresses occurring in the surface layer should contribute to the increase of resistance to contact fatigue in the pins that underwent burnishing.

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