THE ANALYSIS OF THE INFLUENCE OF THE BURNISHING PROCESS ON CORROSION PROPERTIES OF STEEL APPLIED TO SEA WATER PUMP SHAFTS

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Abstract

Angular momentum pumps are very often applied onboard ships. These pumps are used in cooling circuits of medium and high power engines, power plant boilers and in bilge, ballast and fire installations. Very extensive use of angular momentum pumps on board is connected with their numerous advantages. During operation the wear of marine hull, the rotor and shaft seals take place. The research attempts to increase the service life of shafts.

The article presents the research results referring to the analysis of the influence of lathing and burnishing on the corrosion properties of steel applied to marine pump shafts. The research was performed on a roller of 40 mm in diameter made of X5CrNi 18-10 (AISI 304 L) stainless steel.

The lathing process was carried out by means of a WNMG WF 080408 Sandvik Coromant cutting tool with replaceable inserts. The process of burnishing was done by SRMD burnisher by Yamato. In addition, the influence of the burnisher passes number on the corrosion properties was determined.

The paper will present the results of potentiodynamic research. To conduct the survey the Atlas 0531 EU & IA potentiostat will be used. Determination of parameters of the corrosion process will be executed on Elfit2 computer program.

Keywords: *plastic tooling, burnishing, surface layers, angular momentum pump, corrosion properties.*

1. Introduction

Vessels and warships are equipped with main propulsion engines, generating sets and auxiliary machinery which are used in the engine room as well as on deck. Sea water pumps belong to a group of centrifugal angular momentum pumps. Their wide application on board vessels is related to their numerous advantages which comprise simple construction, good performance characteristic, easy adjustment, quiet work and the possibility of applying direct electric motor drive. Centrifugal angular momentum pumps are utilized in the cooling system of high and medium speed engines, for supplying boilers, in bilge systems, ballast systems and in firefighting installations. During their service the wear of pump body, rotor, sealing and shaft takes place. The research work made an effort to improve the shafts service durability and was based on carrying out tests for contact fatigue, friction wear and electrochemical corrosion.

Due to hard service conditions marine pumps working in sea water environment are made of corrosion resistant materials. In spite of the fact that pump shafts are made of an expensive material, it is not possible to avoid service damage. This damage includes cracking, plastic deformation, excessive wear of pins in places of mounting rotor discs and sealing chokes, corrosive wear, friction wear, erosive wear and splineways knock outs. During service experience the most common problem that is observed is excessive wear of pins causing their diameter decrease as well as exceeding the permissible shape deviations in place of chokes mounting.

Technology used in production process has a vital influence on the reliability and service life 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 [6]. The basic methods of final tooling of shafts include precise lathing, grinding or burnishing operation.

The process of burnishing shafts proposed here aims at increasing the service durability of marine pump shafts of sea water installations, which should give economic benefits in comparison with traditional methods. Burnishing process enables the achievement of high smoothness of machined surface together with the surface layer hardening. This process has been performed in industrial experience on universal machine tools and on CNC machines but it is regarded as plastic tooling. Therefore the final formation of dimensions and service properties with the use of burnishing constitutes a chinless and dustless treatment, which allows for ranking burnishing among ecological tooling methods. The review of literature pointed out three fundamental purposes of the application of burnishing in the machine elements production process:

- smoothness tooling – which results in the reduction of the surface roughness after machining that precedes burnishing,
- strengthening tooling – which increases service properties (i.e. resistance to fatigue wear, abrasive wear and corrosive wear) by change of material properties in the surface layer,
- dimension-smoothness tooling – which increases the dimension accuracy with simultaneous reduction of surface roughness to its required value.

Burnishing process enables surface working at high dimensional precision (accuracy class 7 and 6) which makes it possible to achieve such advantages as [6-9]:

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

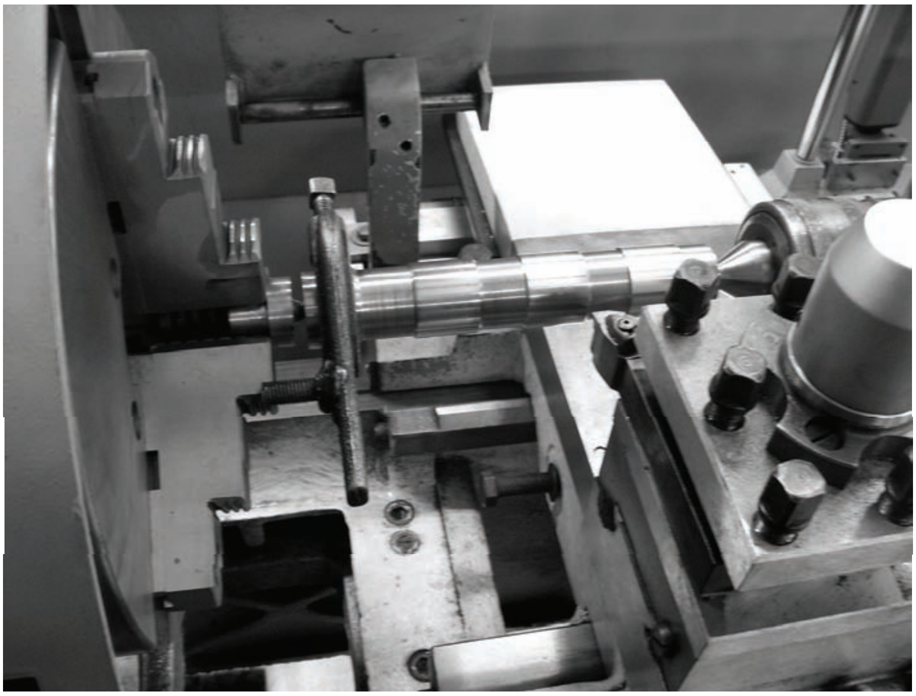
Numerous scientific centres all over the world deal with burnishing treatment and its impact on the surface layer. Research programmes usually cover issues related to burnishing of cast iron, some heat resisting alloys, stainless steel, copper and aluminium alloys, titanium and its alloys, galvanic,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

The surface layer of material is specifically subjected to various degradable factors. However it is not possible to avoid adverse phenomena of surface degradation during working conditions as well as corrosive influence of work environment. Therefore the aim of the paper is to obtain proper technological quality and suitable service properties of angular momentum pump shaft pins applied to sea water systems in marine engines. Within the research, the optymalization of burnishing technological parameters [1-3, 5] was carried out and the influence of the number of burnishing tool passes on the hardness and stereometric parameters of angular momentum pump shaft pins was defined. Therefore burnishing should be performed on account of the minimization of R_a surface roughness factor as well as maximization of S_u surface layer relative hardness degree. The article will present the results of the research on pins corrosive properties in the form of potentiodynamic examinations.

2. Samples preparation

The process of turning and burnishing of shaft pins ϕ 40 mm in diameter, made of X5CrNi 18-10 stainless steel was carried out on a universal CDS 6250 BX-1000 centre lathe. The preliminary lathing process was conducted by a cutting tool with WNMG 080408 WF removable plates by Sandvik Coromant. The super finishing Wiper plates ensure high efficiency of finishing and semi – finishing treatment. Properly designed geometry made it possible to apply two times more feed at the same surface finishing quality in comparison with traditional plates. Therefore during the preliminary lathing (Fig. 1a) the following machining parameters were used: machining speed V_c=112 m/min, feed f=0.27 mm/rev, machining depth a_p=0.5 mm. The process of burnishing was conducted by SRMD one roller burnish by Yamato (Fig. 2). The applied parameters of technological process of surface tooling were presented in Tab. 1. The research also covered the determination of the influence of burnish tool passes number on corrosive properties.

a)



b)

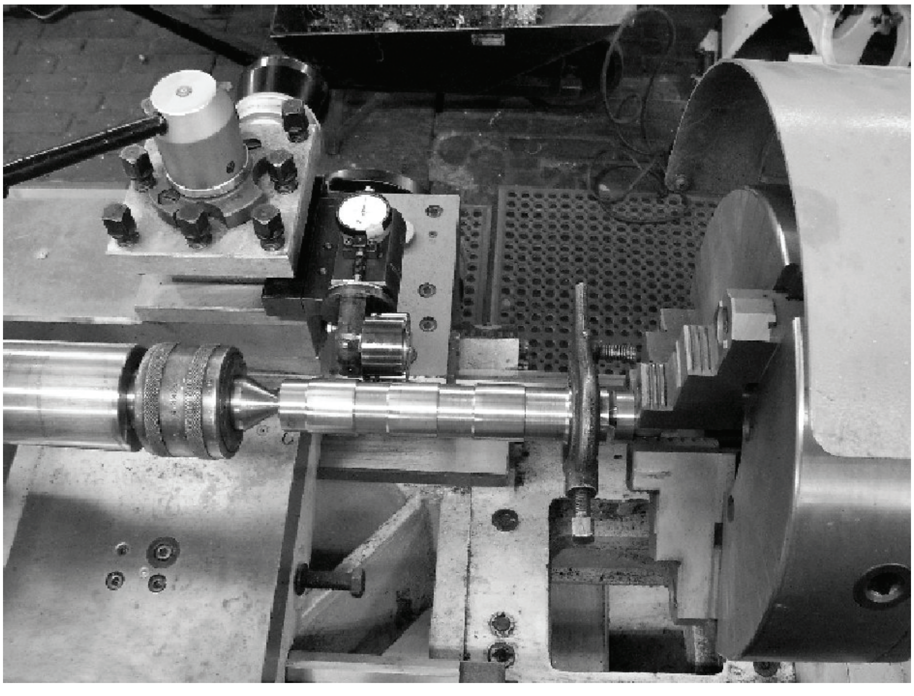


Fig. 1. The view of working assembly (machine tool, fixture, object, tool) - a) lathing b) burnishing

Fig. 2. Burnishing tool

Tab. 1. Technological parameters of burnishing process

Parameter		Values
Burnishing force - F	[kN]	1.1
Burnishing speed – V_n	[m/min]	35
Feed - f	[mm/rev]	0.08

3. Research methodology

The hardness measurement was taken by Vickers method by means of WMP tool at thrust force amounting to 50N, while the surface roughness was measured by HOMMEL TESTER T1000 – a profile measurement gauge. The measuring length was 4.8 mm, and the sampling length was 0.8 mm.

The measurement of corrosion resistance was performed by potentiodynamic method [10] in a tri-electrode system. The degreased sample with the area of 1 cm2 together with auxiliary (polarization) electrode made of plated titanium and reference electrode (calomel saturated electrode) were immersed in a vessel containing substitute sea water (PN-66/C-06502). Before taking measurements the samples were subjected to explosion in electrolyte in order to stabilize the corrosion potential. During measurement the electrolyte was being mixed.

The polarization curve was recorded in the range of ± 150 mV of corrosion potential. Potential change rate, relating to all trials, was 10 mV/min. The Atlas 0531 EU&IA potentiostat was used to execute the examination. The estimation of corrosion process parameters was performed by Elfit2 computer program.

4. Research results

The analysis of the number of burnisher passes on the surface layer strengthening (Fig. 4) showed that the first pass of a burnishing tool has the greatest influence on the hardness change (10% increase). The burnishing process allowing for further burnisher passes does not result in the increase of hardness value of a shaft pin surface being lathed. The surface hardness achieved after consecutive burnisher passes can be related to errors. The results are within the margin of error.

In order to analyze the geometric structure of shaft pins surface more thoroughly the roughness parameters (R_a, R_q, R_z, R_t) obtained in the research were shown in Tab. 2. The exemplary profilegrams as well as material fractions were presented in Fig. 5. The preliminary tooling of shaft pins made it possible to achieve the surface with the mean Ra value equal to 0.61 μm. Further burnisher passes enabled the achievement of this parameter value amounting to Ra = 0.06 μm. Analyzing the remaining parameters it is possible to observe similar relation. Both Rq and the other parameters defining the maximum peaks reach the minimum values after the third burnishing operation. The results obtained [4] confirm that in order to achieve maximum surface smoothness it is important to apply triple burnishing operation.

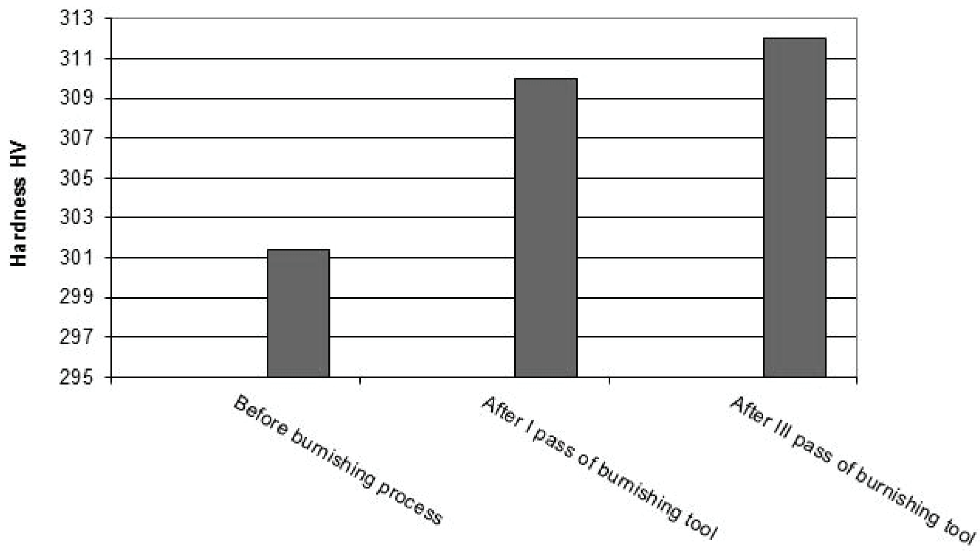


Fig. 4. The influence of burnishing tool passes number on surface layers strengthening (S_U)

Burnishing parameters utilized here had an influence on both the surface roughness value decrease and the surface layer strengthening increase of the treated material. The surface that is characterized by higher accuracy (by decreasing the height and the amount of surface roughness, by eliminating surface damages such as micro cracks and scratches) has a smaller corroding surface, which should improve its corrosion resistance. Whereas, the nonuniform appearance of internal hardening in the surface layer can cause the formation of galvanic microcells in the plastically deformed crystals, they can consequently promote corrosion. Therefore the corrosion resistance of burnished objects depends on two factors: the degree of cold work and surface smoothening. Higher resistance to corrosion can be achieved by the application of smoothness burnishing which is characterized by low cold work. This type of process comprises machining in which the SRMD one roller burnisher is the basic tool.

Tab. 2. Basic parameters of surface roughness

Type of treatment	Roughness parameters			
	R_a [µm]	R_q [µm]	R_t [µm]	R_z [µm]
T roller	0.61	0.76	4.97	3.68
N roller	0.10	0.13	1.09	0.78
3N roller	0.06	0.09	0.95	0.53

Table 3 presents the results of mean electrochemical potential values and corrosive currents density of the shafts examined for the potentiodynamic research. Fig. 7 shows exemplary polarization curves for samples cut off the shaft pins after burnishing. The analysis of the obtained results for corrosion currents density for particular samples demonstrated a slight improvement of resistance to corrosion of the burnished samples.

The average corrosion current density value for shaft pin surface after lathing was 0.8 $\mu A/cm^2$. The burnishing caused almost 44% decrease of Jkor value that is 0.45 $\mu A/cm^2$. Further burnisher passes allowed to decrease the average Jkor value of the corrosion current density three times (0.25 $\mu A/cm^2$) when compared to lathing. The results obtained testify the improvement of corrosion resistance of shaft pins which were subjected to burnishing process. The effect was obtained by decreasing the surface roughness and consequently by decreasing the area of corroding surface.

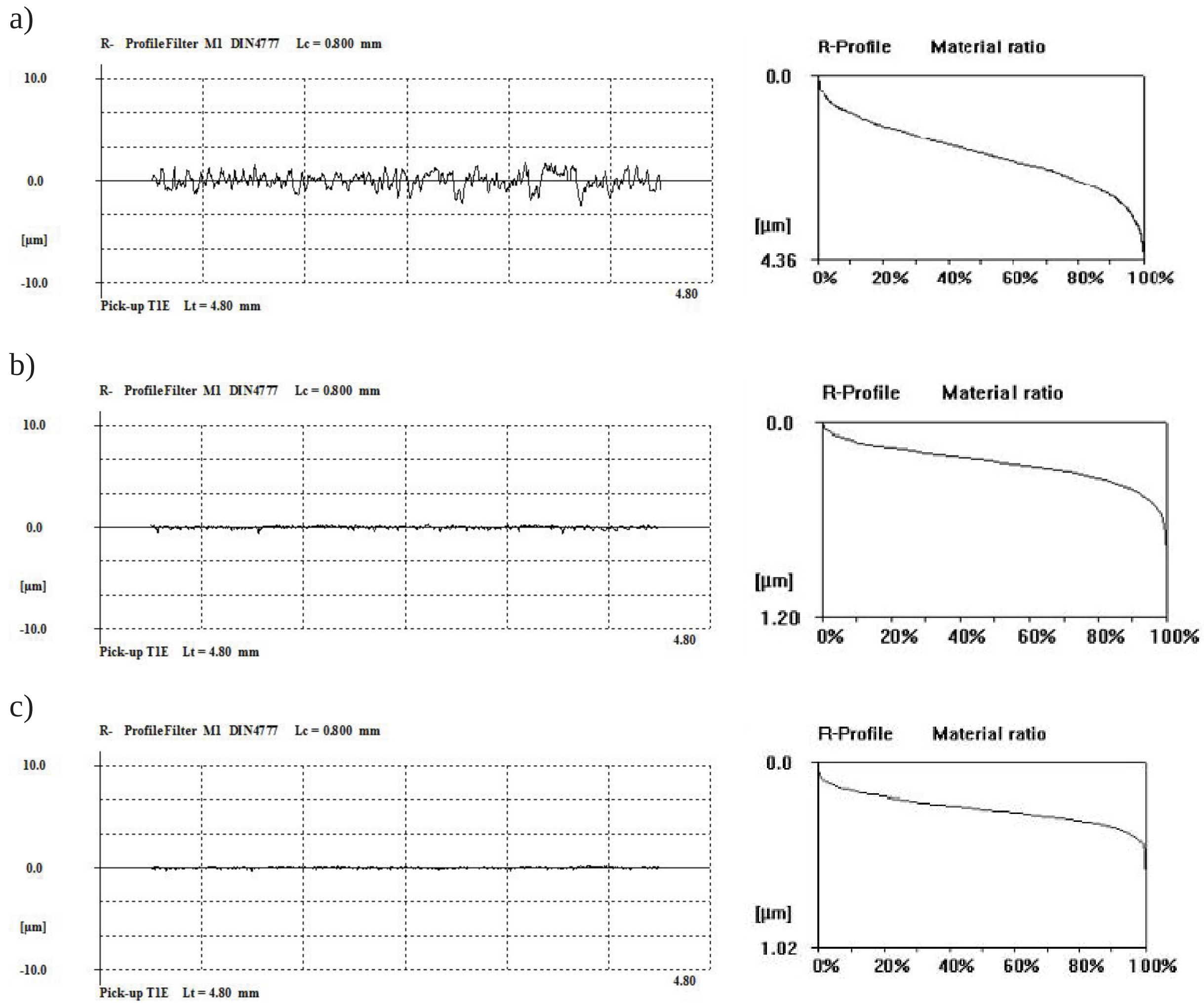


Fig. 5. The shaft surface profile analysis and roller bearing surface : a) before burnishing process R_a=0.61µm, b) after burnishing process R_a=0.10 µm, c) after III pass of burnishing tool R_a=0.06 µm

The corrosion potential value for lathing, however, reached more favourable value (Ec = -189 mV) in comparison to burnishing (Ec = -250 mV). Consecutive passes of a burnishing tool did not cause a distinct decrease of potential, and the difference amounting to 7 mV lies within the standard deviation limit. The average corrosion potentials values obtained for samples after burnishing prove a higher susceptibility to corrosion. However the values of corrosion current density were expressed in decimal parts µA/cm^2, so it can be assumed that for austenitic 304L steel – the resistance to electrochemical corrosion in sea water environment remains at the same level after application of lathing and burnishing.

Tab. 3. The results of potentiodynamic research

Sample	Corrosion potential value Ec [mV]	Standard deviation	Corrosion current density value Jkor [µA/cm^2]	Standard deviation
T roller	-189	5	0.80	0.10
N roller	-250	5	0.45	0.10
3N roller	-257	8	0.25	0.05

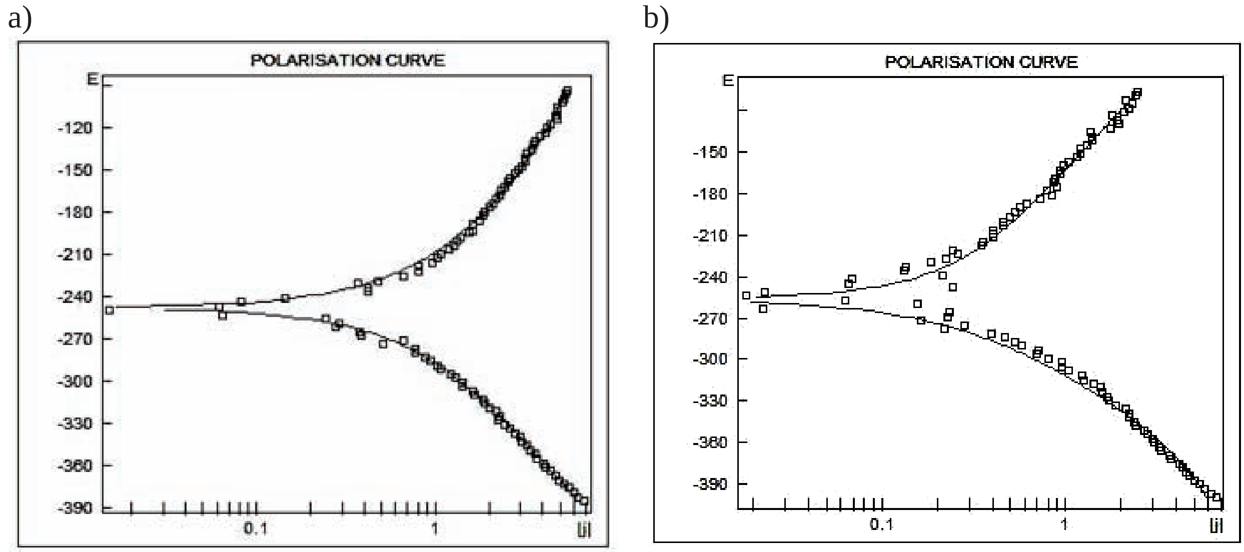


Fig. 7. Exemplary Tafel curves for rollers a) after burnishing b) after 3 passes of burnishing tool

5. Conclusions

The process of burnishing of shaft pins resulted in the decrease of R_a roughness parameter at the simultaneous increase of S_U surface layer relative hardness. Consecutive passes of a burnisher did not cause an additional surface hardening, but allowed to reach a surface of higher smoothness. Thus the process of burnishing that was performed can be recognised as smoothness tooling. Marine pumps operating in sea water conditions are made of proper quality material being protective owing to its chemical composition. The corrosion current density results obtained for shaft pins after lathing and burnishing make it possible to state that burnishing process causes 44% increase of electrochemical corrosion resistance in sea water conditions when compared with lathing.

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