THE ANALYSIS OF FINISH TOOLING INFLUENCE ON CONTACT FATIGUE OF STEEL APPLIED TO SEA WATER PUMP SHAFTS

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Abstract

The article presents the research results referring to the analysis of the influence of finish treatment (lathing, grinding, burnishing) on the contact fatigue of steel applied to marine pump shafts. The research was performed on a roller 25mm in diameter made of X5CrNi18-10 (AISI 304 L) stainless steel. The lathing process was carried out by means of a Sandvik Coromant cutting too, the grinding was done by grinding attachment to a lathe, whereas the process of burnishing was performed by SRMD burnisher by Yamato.

Within the research, the optimalization of burnishing technological parameters was conducted on account of the minimalization of R_a surface roughness coefficient as well as the maximalization of S_U degree of surface layer relative hardness. The multi criteria optimalization conducted by min-max method with regard to minimum surface roughness as well as maximum degree of surface layer hardness demonstrated that burnishing process should be carried out at the following technological parameters: burnishing force 1.1 kN, burnishing speed 35 m/min, feed 0.13 mm/rev. In addition, the influence of the burnisher passes number on the surface layer quality was determined.

It is essential for this research to determine the burnishing influence on the service conditions which comprises the electrochemical corrosion research, friction wear and contact fatigue research. The paper will present the research results of contact fatigue examination of samples after finish machining.

***Key words**: contact fatigue, burnishing, corrosion resistant steel, surface layer, angular momentum pumps*

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 fire fighting 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 [7, 8]. 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 chipless 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 [6-12]:

- 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 [10], some heat resisting alloys, stainless steel, copper and aluminium alloys [11], titanium and its alloys [12], galvanic, diffusive and padded coatings as well as parts produced by sintering metal powders.

The object of the paper is to achieve proper technological quality and to apply suitable service properties to centrifugal pump shafts journals used in ship engine room for sea water. Within the research the optimalization of the burnishing technological parameters was carried out for hardness and for stereo metric parameters of centrifugal pump shafts journals [1, 3, 4,]. Therefore the process of burnishing should be performed with respect to R_a surface roughness minimalization as well as S_U surface layer relative hardness maximalization. It is vital to define the influence of burnishing on service conditions by: testing electrochemical corrosion, friction wear and contact fatigue. The results related to testing contact fatigue of samples after finish lathing, grinding and burnishing will be presented in the paper.

2. Samples preparation

Finish tooling of shafts pins was carried out on a CDS 6250 BX-1000 universal centre lathe. Shafts pins ϕ 40 mm in diameter and made of X5CrNi 18-10 stainless steel were machined.
The process of finish lathing was conducted by a knife with replaceable plates WNMG 080408

WF type (super finishing plates) by Sandvik Coromant (Fig. 1). During turning the following machining parameters were applied: machining speed V_c=112 m/min, rate of feed f=0.27 mm/rev and machining depth a_p=0.5 mm. The grinding process was performed by grinding attachment for lathes (Fig.2). The 1 - 80x10x32 - 99C 80-N V grinding wheel was used for the process.

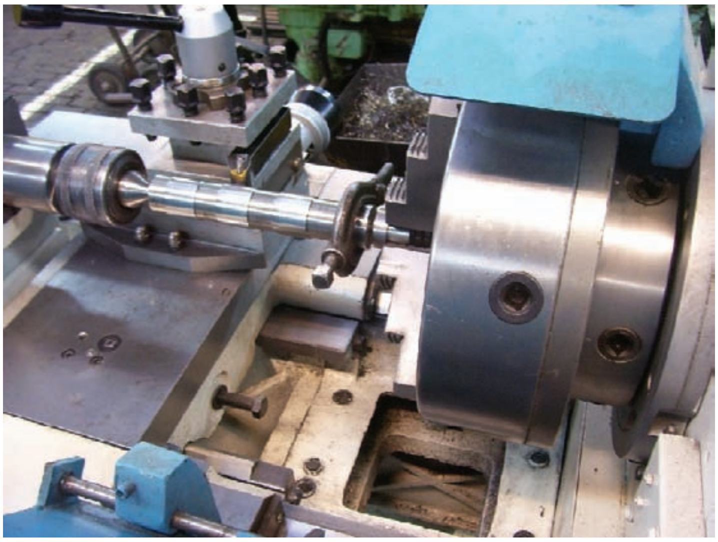


Fig. 1. General view of OUPN tooling system (machine, grip, object, tool) – finish tooling

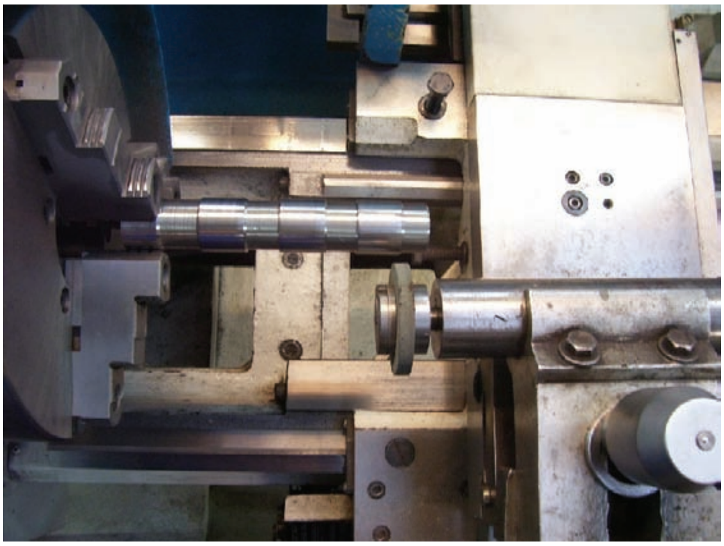


Fig. 2. General view of OUPN tooling system (machine, grip, object, tool) – grinding

The process of burnishing (Fig. 3) was conducted by SRMD one roll burnish by Yamato (Fig. 4). The technological process parameters applied for surface plastic treatment are shown in Tab. 1. The influence of the number of burnisher passes on surface roughness and surface layer hardness [2] was also determined within the research. A shaft journal after three applications of burnishing tool was used for the contact fatigue test experiment, with the technological parameters included in Tab. 1.

3. Research methodology

The experiment was conducted on a stand (Fig. 5), constructed according to PN-H 04324.1980 standard guidelines –(Metals. Contact wear tests.) The tests deal with the process of physical properties changes occurring on the contact surface and in the area located directly under the contact surface. The wear phenomenon is caused by the change of load value or by relative load displacement along the contact surface. Therefore the stand was equipped with a force sensor of 0 – 2 kN range, a MW2006-4 two-channel gauge as well as PP203 computer program. The device cooperates with torque meters MI and MIR type made by PIMR Poznań and fitted with rotary – impulse converter based on HAL320 integrated circuit. While conducting fatigue test the course of force changes was monitored. The example run of force alterations in 1 second is shown in Fig. 6.

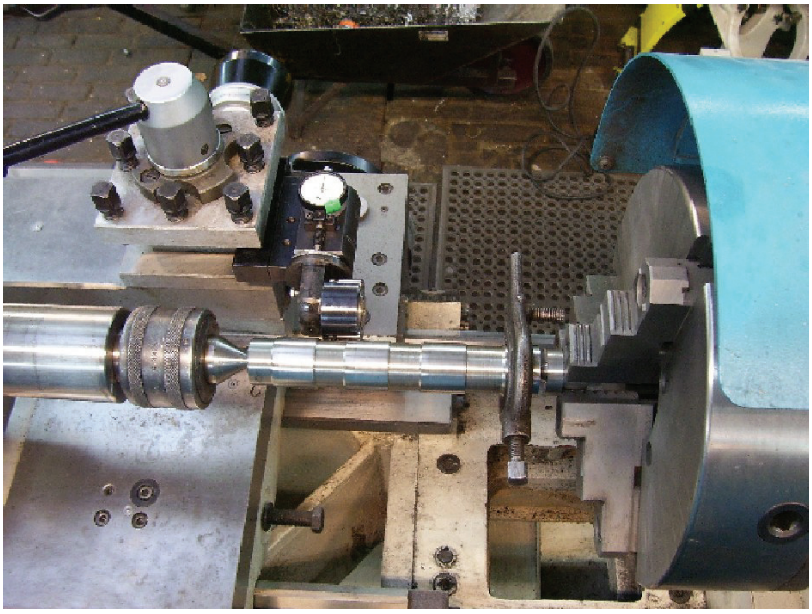


Fig. 3. General view of OUPN tooling system (machine, grip, object, tool): burnishing

Fig. 4. 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]	0.13

Fig. 5. Contact wear test stand

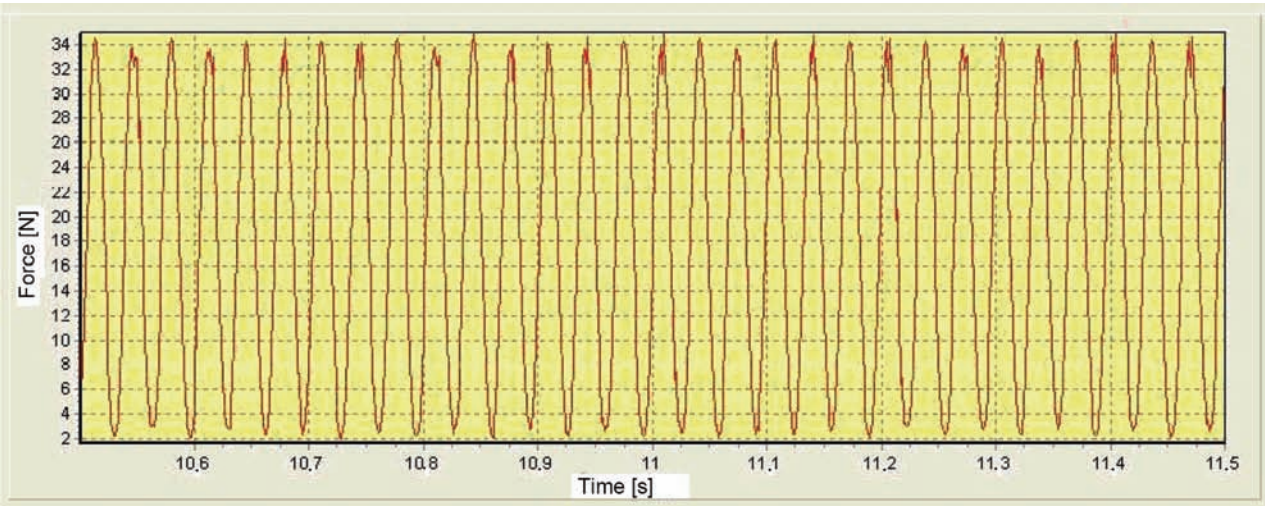


Fig. 6. The record of force run in 1 second

The microscope examinations of shafts pins surface after finish tooling were carried out by (SEM) Philips XL30 scanning electron microscope whereas macroscope examinations were conducted by means of Zaiss Axiovert 25 optical microscope.

4. Research results

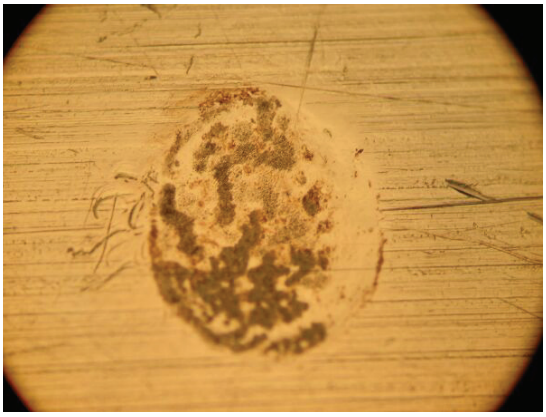
Four samples underwent contact wear fatigue at constant contact. The samples were previously subjected to finish lathing (Fig. a), grinding (Fig. b), burnish tooling (Fig. c) as well as three passes of burnishing tool (Fig. d). The load conditions were kept within ± 1.5% of maximum force F_c. On the basis of Hertz formula the maximum contact force was determined F_c = 35.4 N. The standard recommendations referring to the basis for contact fatigue examination define the number of cycles that is $N_G = 2*10^7$. So the number of cycles accepted for the experiment for the samples was $1.726*10^8$. The occurrence of cracks or fatigue chipping on the sample surface was considered to be a criteria for samples damage during contact wear test.

After conducting the experiment, some material defects such as wear chipping of surface layer were observed. Example photographs of 20 times magnification of samples that underwent contact fatigue test are shown in Fig. 7.

a

b

c



d

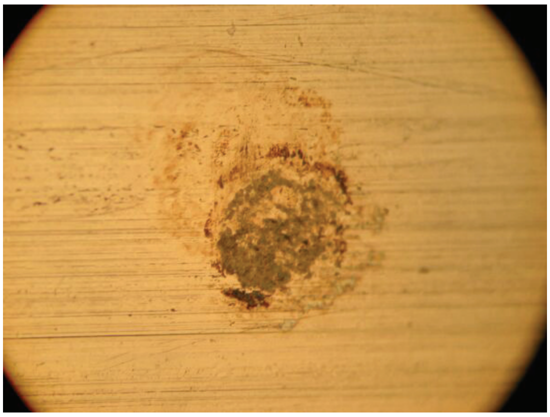


Fig.7. Example photos of samples after conducting contact fatigue test that were subjected to: a) finish lathing, b) grinding, c) burnishing, d) 3 burnish passes

The measurements of surface layer area where the chipping occurred was performed by means of planimeter. After surface layer finish lathing the chipping was 10.6% compared to the whole area examined by microscope. After burnish process the material chipping value was 8.6%. Burnish tooling comprising three tool passes decreased the surface layer chipping area to 5%.

In order to analyze the surface layer in place of force interaction more thoroughly, additional examinations on SEM scanning microscope were carried out. Example pictures are shown in Fig. 8.

5. Conclusions

The application of optimalized burnishing parameters enables the achievement of a surface with specifically beneficial properties. Burnish process applied to pump shafts after preliminary machining makes it possible to obtain a surface layer with higher degree of relative surface hardness at simultaneous roughness decrease when compared with traditional finish tooling methods. Burnishing the surface of marine angular momentum pump shafts journals made of X5CrNi 18-10 stainless steel contributed to higher contact fatigue resistance in comparison with finish lathing. Consecutive applications of burnish tool improved surface resistance to contact fatigue. The results analysis proved that the process of grinding is equal to 3 burnish tool passes, as the area of surface layer chipping is of the same size. The technological process of burnishing is to ensure the highest material resistance to contact fatigue and should comprise three passes of burnish tool.

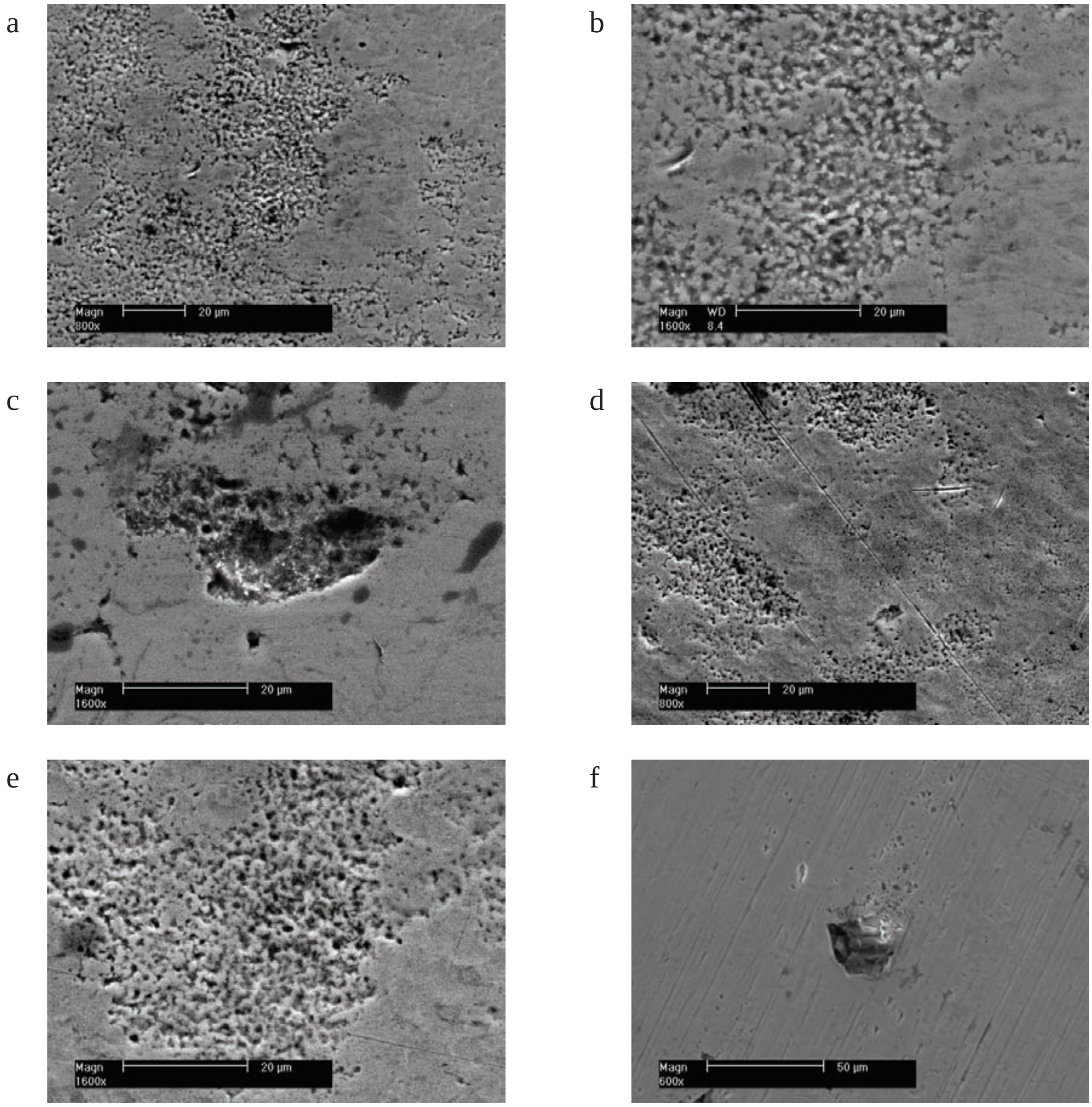


Fig.8. Examples of surface photos taken by SEM scanning microscope: a). b), c) ground sample; d), e) – burnished sample; f) sample after 3 burnish tool passes

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