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THE ANALYSIS OF FINISH TOOLING INFLUENCE ON WEAR INTENSITY OF MARINE PUMP SHAFT

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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 as well as bilge, ballast and fire installations. Such an extensive use of angular momentum pumps on board is connected with their numerous advantages. However during operation the wear of marine hull, the rotor and shaft seals takes 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 finish treatment (finishing turning, grinding, burnishing) on the friction of steel applied to marine pump shafts. The research was performed on a roller 39 mm in diameter made of 304L stainless steel. The finish tooling of pump shaft pins was carry out on a universal centre lathe. The finish turning process was carried out by means of a WNMG WF 080408 Sandvik Coromant cutting tool with replaceable inserts. The grinding process was performed by grinding attachment for lathes. The 1-80x10x32-99C 80-N V grinding wheel was used for the process. The process of burnishing was done by SRMD single roll burnishing tool by Yamato. The burnishing process was 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 number of burnishing tool passes on the friction was determined. The paper will present the research results of test on the wear intensity examination of samples after finish machining. The experiment was performed on block – roll tester machine.

Keywords: *plastic tooling, burnishing, stainless steel, angular momentum pump, wear intensity*

1. Introduction

One of the greatest problems of modern production techniques is the achievement of an appropriate quality at minimal costs and accompanied by the production efficiency increase. Therefore while designing the production process, the technology used should have a considerable influence on the durability and reliability of machine parts to be produced. During finish treatment the final dimensions as well as functional properties are imparted to a given element by application of proper treatment type. The process engineer has a range of production techniques to choose for the proper surface layer formation. It is crucial to find a suitable solution which will meet the requirements as well as the work conditions of a given machine part. The traditional finish treatment methods of marine pump shafts include grinding and finish turning. Industrial requirements make it necessary to reach the surface of high precision (3–5 accuracy class) simultaneously ensuring the roughness of R_a = 0.16–0.01 µm. Such an effect can be obtained by proper treatment methods of high accuracy.

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.

The 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. 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 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 [9, 10]:

- ability to reach high surface smoothness (R_a = 0.32-0.04 μm)
- increase of the surface hardness,
- increase of resistance to surface as well as volumetric fatigue,
- increase of resistance to abrasive and scuffing,
- lack of abrasive grain, chips, sharp and hard built-up edge fragments and 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 specific cases,
- high process efficiency (one pass of a tool) and reduction of production costs,
- high durability of burnishes,
- reduction of expenses related to machine parts production.

Many scientific centres all over the world deal with burnishing treatment. Research programs usually cover issues related to burnishing of cast iron, some heat resisting alloys, stainless steel, copper and aluminium alloys, titanium and its alloys, composite and intermetallic coatings [4, 5, 8] 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 optimization of burnishing technological parameters 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.

2. Samples preparation

The process of finish machining of shaft pins ϕ39 mm in diameter, made of X5CrNi18-10 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. 1) the following machining parameters were used: machining speed V_c = 112 m/min, feed f = 0.13 mm/rev, 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.

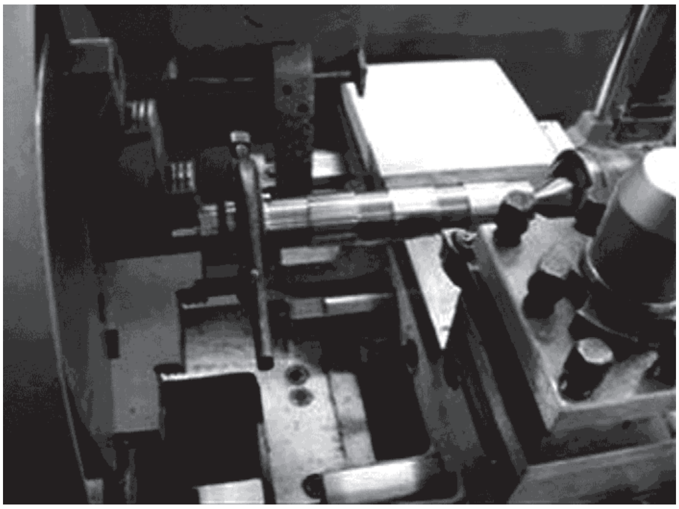

Fig. 1. The view of working assembly (machine tool, fixture, object, tool) – lathing

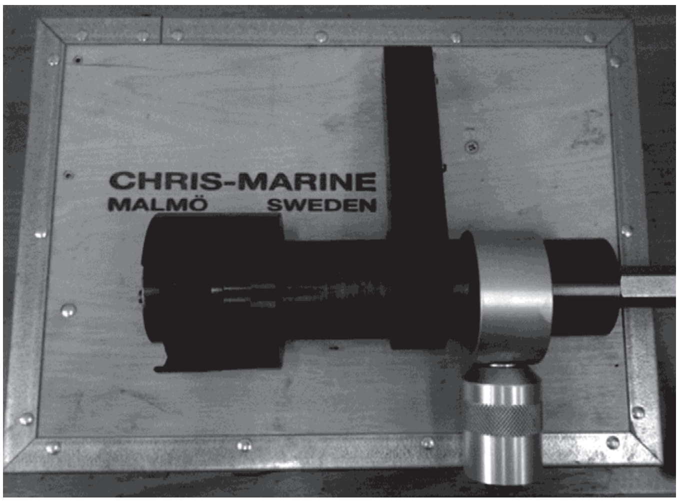

Fig. 2. Grinding attachment for lathes

The process of burnishing (Fig. 3) was conducted by SRMD single roll burnishing tool by Yamato (Fig. 4). Within the research, the optimization of burnishing technological parameters was conducted on account of the minimization of R_a surface roughness coefficient as well as the maximization of S_u degree of surface layer relative hardness [1, 3, 6, 7]. The multi criteria optimization conducted by min-max method [2] 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. 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 friction wear.

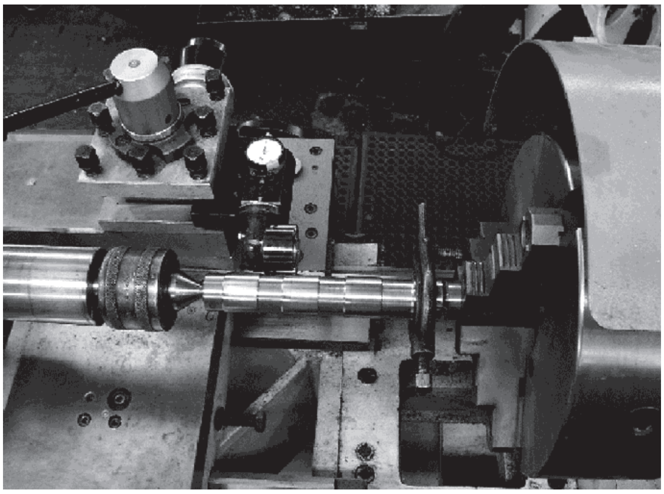

Fig. 3. The view of working assembly (machine tool, fixture, object, tool) – burnishing

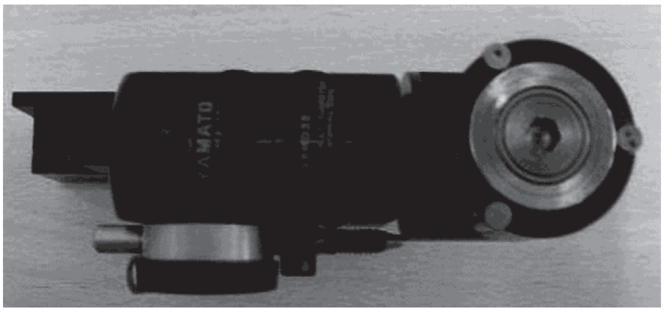

Fig. 4. Burnishing tool

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]	0.08

2. Research methodology

T-05 tester (Fig. 5) is designed to examine the tribologic properties of lubricating agents such as plastic grease, oil, solid oil. It can be used to test the resistance to material wear during metal and plastic friction and also to test the resistance to mashing layers applied to machine elements of great load. The tester allows to carry our examinations according to the requirements of the following standards: ASTM D 2714, ASTM D 2981, ASTM D 3704, ASTM G 77.

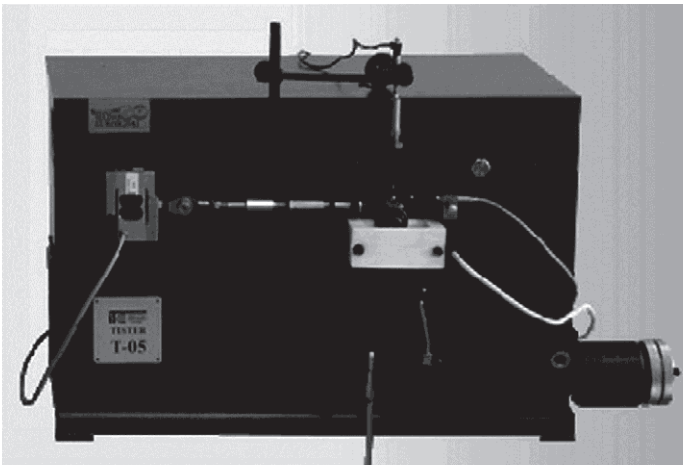

Fig. 5. Block – roll tester machine

The tribologic characteristics were assigned for the cooperating elements manufactured by means of different finish treatment methods, used in the process of marine pump shafts production. The experiment consisted in pressing down the immovable counter sample (a block) with a given force *P* on a roll revolving in one direction at a given speed which constituted a sample made of stainless steel that underwent proper technological production process. The examination of wear intensity was performed by measuring the mass decrement at 10 min intervals. The mass decrement was measured by an electronic weighing machine at an accuracy of 0.0001 gram. All parameters of the examined friction wear are presented in Tab. 2.

Tab. 2. Research plan of wear intensity

Wear intensity at *n* = 600 rev/min and *P* = 600 N						
Time [min]	10	20	30	40	50	60

3. Research results

The research results of mass decrement in a time unit by sample and counter sample wear for the analysed production technologies are shown in Fig. 6 to 9.

The friction wear measurements that were conducted proved that the highest mass decrement occurred in case of ground shaft pins (Δm = 114 mg – at testing pass time = 60 min). The lowest wear was observed in case of shafts that were burnished three times. After 60 minutes of tribometer work, the 81 mg of mass decrement was noted.

Tribological examinations (Fig. 10) showed that during the first 10 minutes of testing pass time the turned shaft pins suffered the most intensive wear (*I* = 122 mg/h). The lowest wear intensity was observed for the shafts that were burnished 3 times (*I* = 79 mg/h). It should be noted, however,

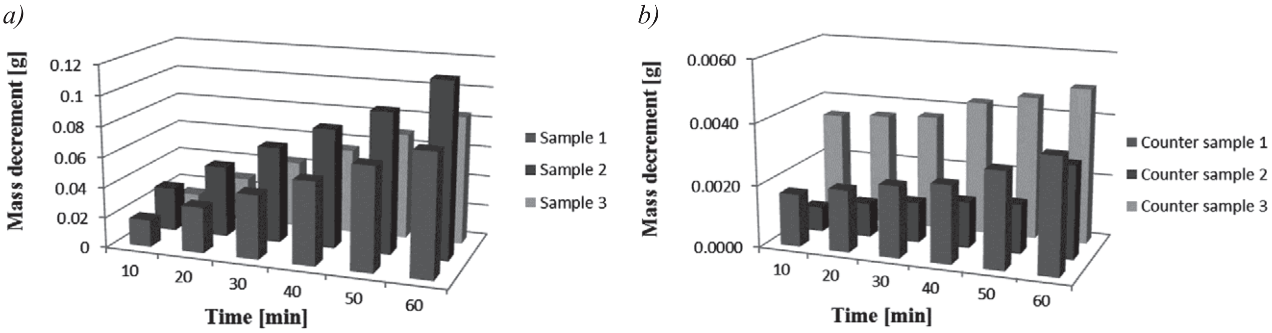

Fig. 6. Mass decrement graphs of a sample after turning (a) and a counter sample (b)

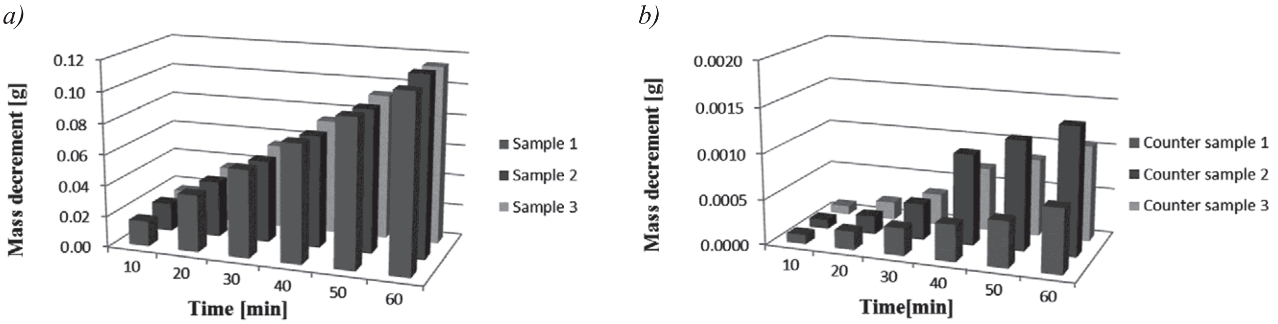

Fig. 7. Mass decrement graph of a sample after grinding (a) and a counter sample (b)

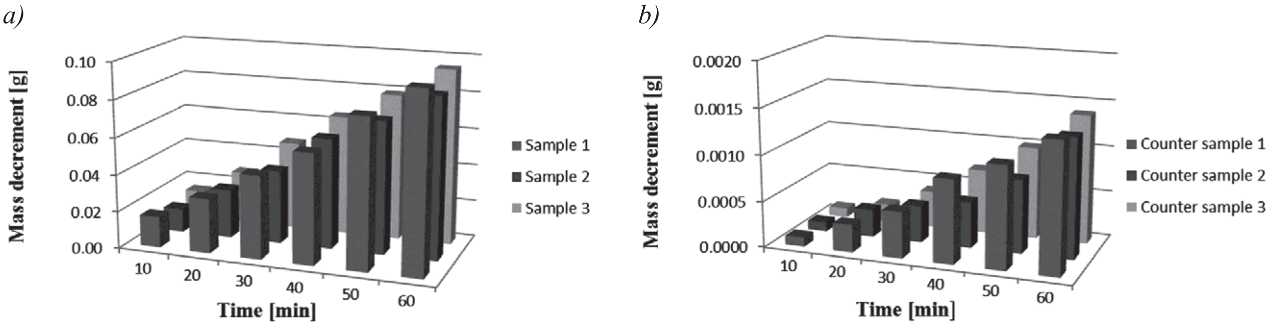

Fig. 8. Mass decrement graphs of a sample after burnishing (a) and a counter sample (b)

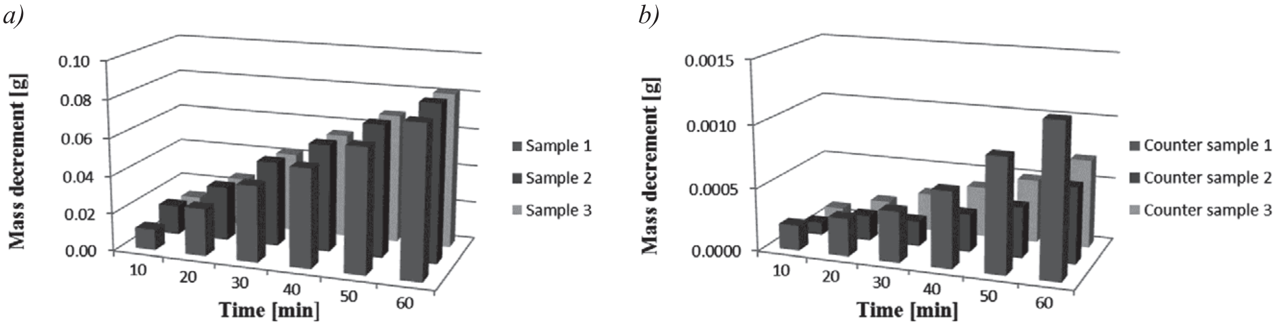

Fig. 9. Mass decrement graphs of a sample after 3 burnishing tool passes (a) and a counter sample (b)

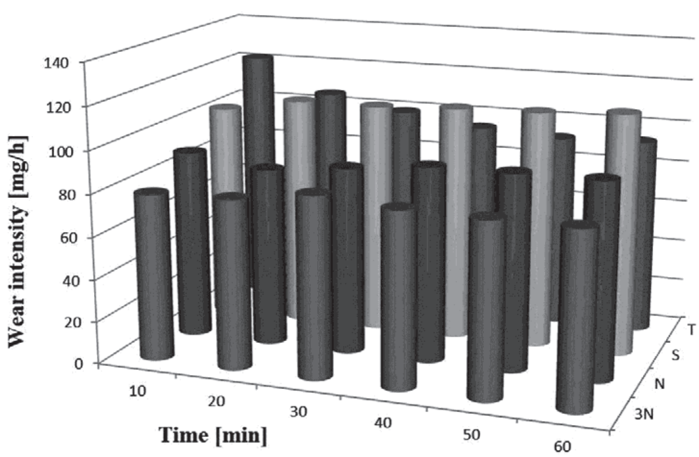

Fig. 10. Wear intensity for samples after finish turning (T), grinding (S), burnishing (N), and 3 passes of burnishing tool (3N)

that the wear intensity values for turned shafts was decreasing with time and reached the value of $I = 90$ mg/h. And the wear intensity of ground shaft pins was increasing during the examination process time from 103 mg/h to 114 mg/h. In case of shafts that were burnished once or three times the wear intensity was actually not changing. We can conclude, therefore, that in case of burnished shafts the effect of lapping does not occur on plastically treated pins surfaces.

The exemplary photographs of tribological surface pairs for particular finish treatment types is presented in Fig. 11.

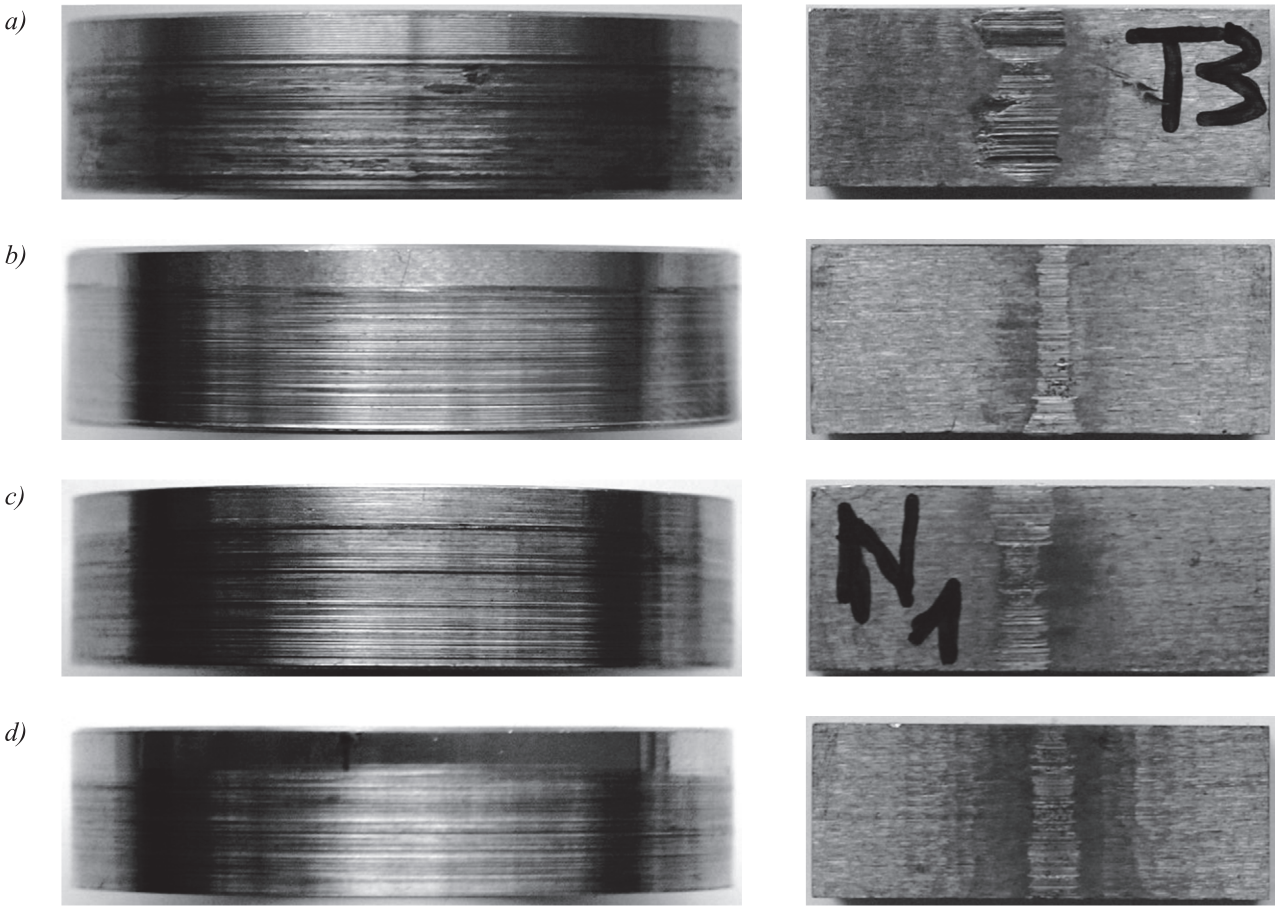

Fig. 11. Tribological pairs of wear intensity test. Sample: a) after finish turning, b) after grinding, c) after burnishing, d) after 3 passes of burnishing tool

4. Conclusions

The application of burnishing process increases the resistance to wear intensity of marine pump shafts working in sea water environment, when compared to traditional finish treatment methods. The shafts that were burnished three times showed the lowest mass decrement among the pairs tested for friction. The highest mass decrement was noted for ground shaft pins.

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