THE ANALYSIS OF INFLUENCE ON FRICTION FACTOR AT CONSTANT FORCE FOR MARINE PUMP SHAFTS AFTER FINISHING TREATMENT

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Abstract

Angular momentum pumps are very often 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 factor 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 factor was determined. The paper aimed at defining the influence of burnishing on service conditions by: testing electrochemical corrosion, friction wear and contact fatigue. The work presented the research results of friction factor tests of the samples after finish turning, grinding and burnishing. In addition, the influence of the burnisher passes number on the friction factor was determined. The experiment was performed on block – roll tester machine.

Keywords: *plastic tooling, burnishing, stainless steel, angular momentum pump, friction factor*

1. Introduction

A popular ability of a material to resist wear in given friction conditions is called resistance to tribologic wear. According to recent literature, the mechanism of the phenomena occurring during mechanical wear of surface layer and its relation with the finish treatment applied, is mainly connected with the comparison of quantitative dependence between the wear in the comparable operating conditions of surfaces that underwent various ways of surface layer formation.

The laboratory research on surface layer wear mechanisms applied in the field of machine construction is related to the exact application in industry, which has a direct correlation with the fact that the surface layer must have strictly defined values. Therefore a wide knowledge of the dependence between microstructure, hardness and tribologic properties is required. From the point of view of tribology the most important changes that the burnishing technology introduces into the surface layer are related with surface roughness and hardness. During the cooperation of a tribologic pair, the changes in surface structure and geometry occur when compared to the initial state. During the process of abrasive and corrosive wear in the technological surface layer it is possible to observe the deformation processes of the roughness peaks, their abrasion and ridging which results in its permanent transformation. The surfaces without sharp peaks are characterized by better resistance to abrasion.

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 optymalization 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

Finish tooling of shafts pins was carried out on a CDS 6250 BX-1000 universal centre lathe. Shafts pins ϕ39 mm in diameter and made of X5CrNi18-10 stainless steel were machined. The process of finish turning was conducted by a cutting tool with replaceable plates WNMG 080408 WF type (super finishing plates) by Sandvik Coromant (Fig. 1).

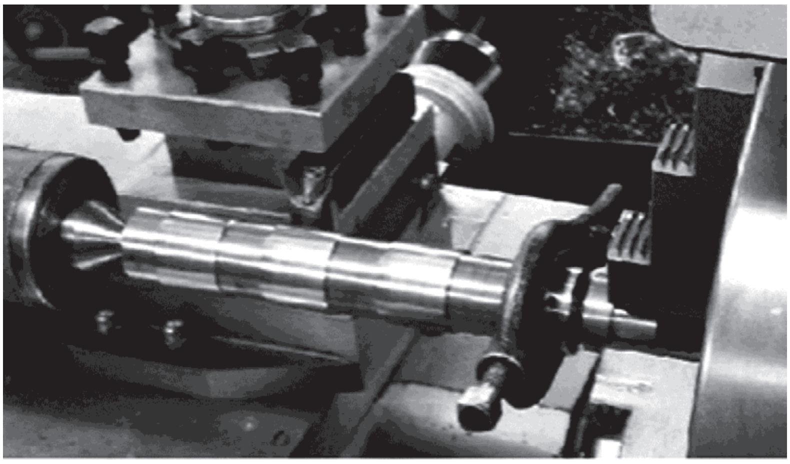

Fig. 1. The view of working assembly (machine tool, fixture, object, tool) – lathing

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. 2a). The 1-80x10x32-99C 80-N V grinding wheel was used for the process.

The process of burnishing was conducted by SRMD single roll burnishing tool by Yamato (Fig. 2b). 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.

a) *b)*

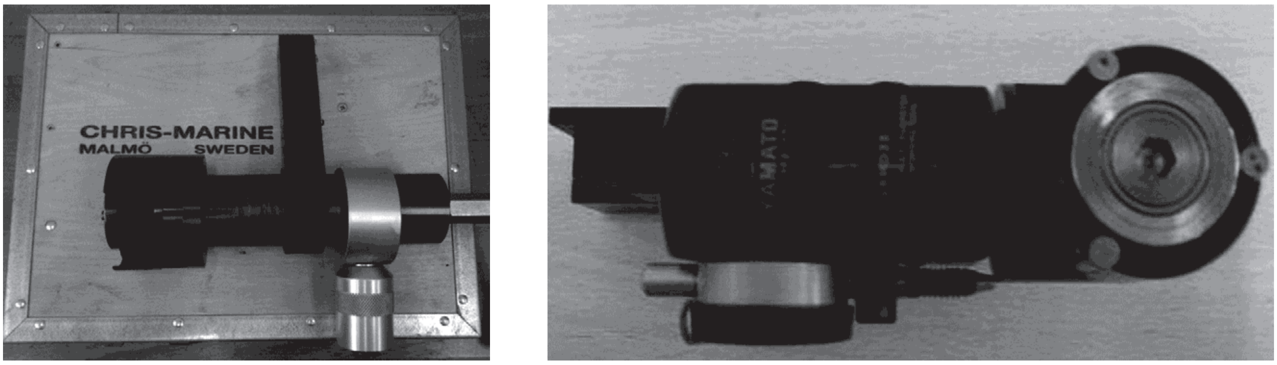

Fig. 2. Grinding attachment for lathes (a) and burnishing tool (b)

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

T-05 tester (Fig. 3) 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.

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 tests defining the influence of rotational speed changes on friction factor change were conducted on T05 machine at constant load. The counter sample was made of C45 material. The tribological couple was lubricated by machine oil enriched with a MotorLife additive. All parameters of the examined friction wear are presented in Tab. 2.

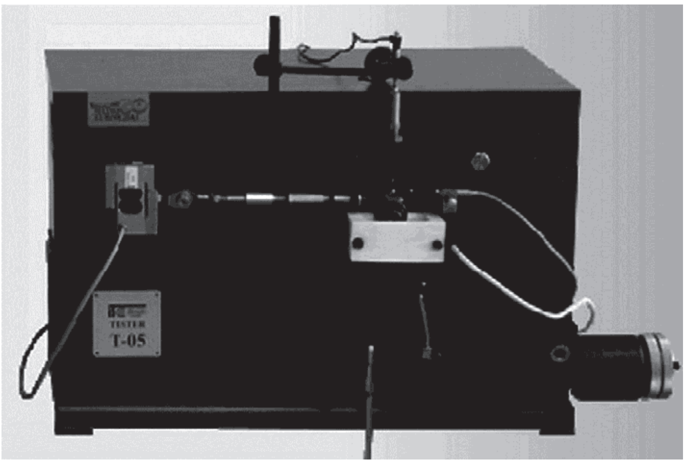

Fig. 3. Block – roll tester machine

Tab. 2. Research plan of wear intensity

The effect rotational speed of change at constant load P = 600 N						
Rotational speed [rev/min]	100	200	300	400	500	600

4. Research results

The research related to tribological wear aimed at defining the highest resistance to surface friction wear of marine shaft pins that underwent burnishing. these examinations had a comparative character. During the service of angular momentum pumps properly shaped shaft pin surface can cooperate with the gland provided with a soft seal (flexible one) or with a slide gland. The application of burnishing process to 304L stainless steel enabled the achievement of such a geometric structure of the surface which was characterized by a considerable decrease of roughness value as well as the surface material ratio. The mean values results of roughness parameters and the parameters of material ratio curve were presented in Tab. 3 and 4. The surface burnishing process had a positive effect on tribological wear resistance by decreasing the protruding surface roughness summits.

Tab. 3. The mean values of surface roughness parameters for finish treatment

Parameters	R_a [µm]	R_q [µm]	R_t [µm]	R_z [µm]
Grinding	0.28	0.36	2.66	2.07
Finish turning	0.35	0.42	2.47	2.03
Burnishing – 1 tool passes	0.07	0.09	0.85	0.59
Burnishing – 3 tool passes	0.06	0.09	0.95	0.53

Tab. 4. The mean values of material ratio parameters for finish treatment

Parameters	M_{r1} [%]	M_{r2} [%]	100% M_{r2}	R_{pk} [µm]	R_{vk} [µm]	R_k [µm]
Grinding	9.03	86.63	13.37	0.34	0.46	0.86
Finish turning	6.47	87.73	12.27	0.25	0.49	1.17
Burnishing – 1 tool passes	7.6	90.1	9.9	0.09	0.14	0.24
Burnishing – 3 tool passes	8.2	87.6	12.4	0.08	0.13	0.21

The influence of rotational speed on friction factor change at constant load was shown in Fig. 4.

Friction factors that were obtained show that the value of μ_t (0.1) at 200 rev/min signifies that during the first cycle the research a considerably high friction of sample and counter sample peaks took place. The loads applied could have caused a quick lapping of the cooperating surfaces. The other

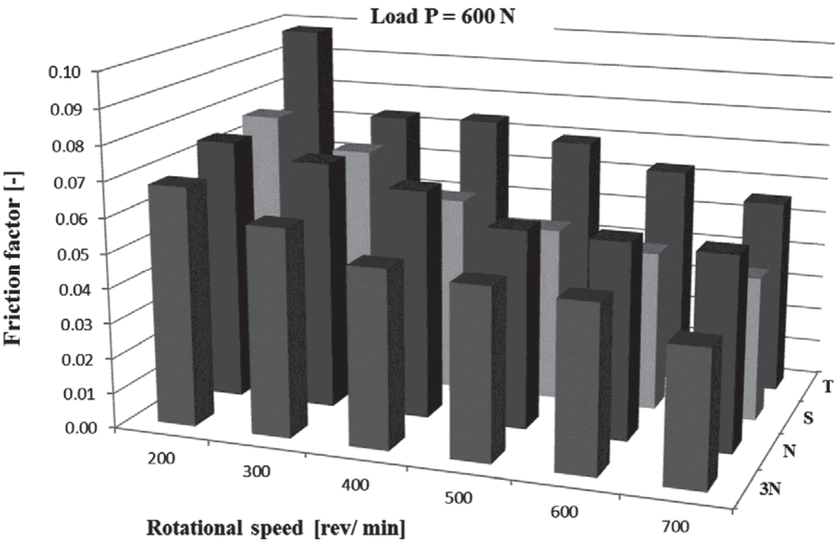

Fig. 4. The diagram of rotational speed influence on friction factor at constant load for samples after: finish turning (T), grinding (S), burnishing (N), and 3 passes of burnishing tool (3N)

analyzed samples were characterized by similar μ_t values at the rotational speed of 200 rev/min. The μ_t factors took similar values for all the samples at the rotational speed of 300 rev/min. When increasing the rotational speed values the sample after grinding has a minimally lower μ_t values in comparison to the samples after lathing and burnishing. The tribologic pair that underwent three passes of a burnishing tool was characterized by the best properties. The research results obtained show that the increase of rotational speed is accompanied by the decrease of friction factor value for each analyzed sample. The highest μ_t values were noted for the sample after finish turning which denotes the worst cooperation of a matched pair.

A significant decrease of roughness parameter values and a slight increase of hardness affected the improvement of operating conditions. Planishing the surface roughness caused the increase of resistance to corrosion because this surface has a smaller corrodible surface. On the other hand a small hardening in the surface layer does not cause the formation of galvanic micro cells, which can speed up corrosion, in plastically deformed formation crystals.

The exemplary samples surfaces after conducting tests were shown in Fig. 5 to 8. It is possible to see the traces of direct reaction of counter sample on the sample. It probably results from the fact that the lubricating medium layer has a thickness bigger than the height of the micro roughness of the rubbing surfaces which contribute to the tribologic pair lapping during the first research stage.

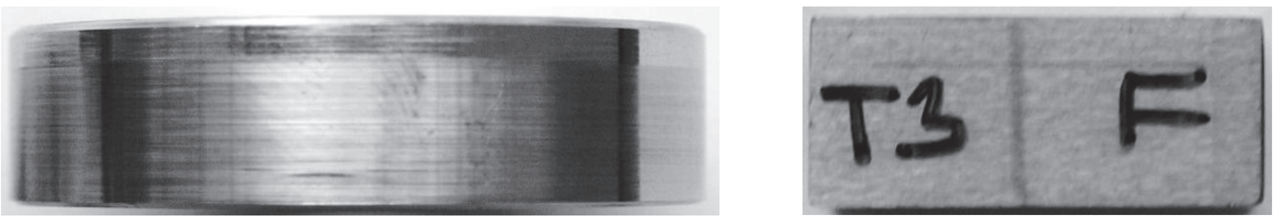

Fig. 5. The view of the surface layer after conducting the test on the influence of rotational speed on μ_t. Turned sample

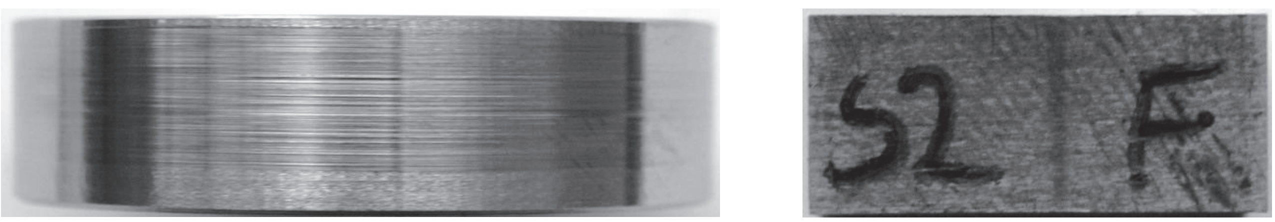

Fig. 6. The view of the surface layer after conducting the test on the influence of rotational speed on μt. Grinded sample

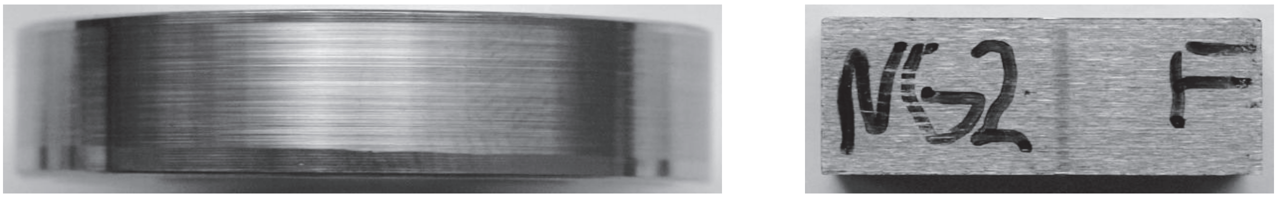

Fig. 7. The view of the surface layer after conducting the test on the influence of rotational speed on μ_t. Burnished sample

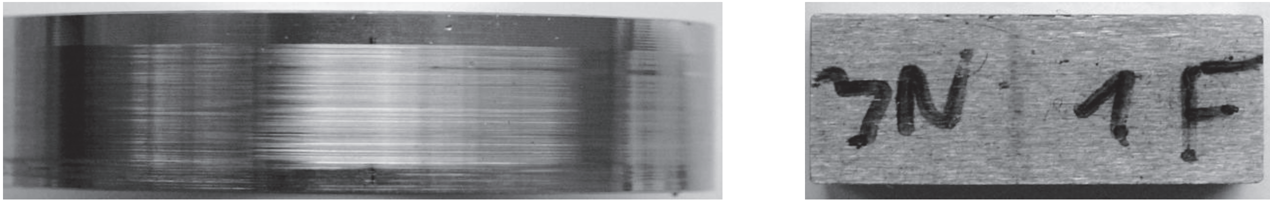

Fig. 8. The view of the surface layer after conducting the test on the influence of rotational speed on μ_t. Sample after 3 passes of burnishing tool

5. Conclusions

Planishing the surface by reducing the protruding surface roughness peaks improved the resistance to tribologic wear. The analysis of the influence of sample rotational speed at its constant load showed that the lowest friction factor in the whole range of loads belonged to shaft pins that underwent burnishing treatment comprising three passes of burnishing tool.

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