THE INFLUENCE OF BURNISHING PROCESS ON SURFACE ROUGHNESS OF STAINLESS STEEL RESEARCHED BY OPTICAL PROFILER

LABUDA Wojciech [1], KHUDOLEY Andrei [2]

e.g. [1]Gdynia Maritime University, The Faculty of Marine Engineering, Gdynia, Poland, *wlabuda@am.gdynia.pl*

[2]A.V.Luikov Heat and Mass Transfer Institute National Academy of Sciences of Belarus, High-precision Surfacing Laboratory, Minsk, Belarus, *khudoley@hmti.ac.by*

Abstract

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 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 article presents the research results referring to the analysis of the influence of burnishing process on surface topography of marine pump shaft. The research were performed on a shaft made of X5CrNi18-10 (AISI 304 L) stainless steel. The preliminary turning process was carried out by means of a WNMG 080408 WF Sandvik Coromant cutting tool with replaceable inserts. The process of burnishing was done by Yamato SRMD burnisher. The goal of the paper was to define the influence of burnishing tool passes number on surface roughness parameter. The surface topography was measured by MicroXAM-800 optical surface profiler.

Keywords: Burnishing process, surface roughness, surface topography, stainless steel, marine pump shaft

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 the deck. Sea water pumps belong to a group of centrifugal angular momentum pumps. 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 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. 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. Burnishing technology can be used in machine production plants. It allows to eliminate traditional finish machining such as: lathing, grinding, super finishing, honing and polishing.

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, reducing the expenses related to machine parts production.
Many scientific centres, including the Gdynia Maritime University, deal with issues related to the finishing treatment surface of the difficult-to-machine [1-7]. Article presents the research of the influence of burnishing tool passes number on the surface topography of marine pump shaft pins was measured by optical surface profiler.

2. RESEARCH METHODOLOGY

The rollers of X5CrNi1810 stainless steel were preliminarily machined so as to prepare the shaft pins for burnishing. The process of turning was carried out on a lathe CDS 6250 BX-1000 type by a cutting tool with removable inserts WNMG 080408 WF type of Sandvik Coromant. The inserts by Wiper technology 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 turning process (**Figure 1a**) the following machining parameters were used: machining speed Vc = 112 m/min, feed f=0.27 mm/rev, machining depth ap=0.5 mm. After turning the mean value of surface roughness was Ra=880 nm.

The process of burnishing was carried out on TUC 40 lathe. The process was conducted by SRMD one roller burnish by Yamato (**Figure 1b**). The applied parameters of technological process of surface tooling were presented in **Table 1**. The research also covered the determination of the influence of burnish tool passes number on surface roughness.

3D surface topography 110-140 µm was measured by non-contact white light interferometry system - optical surface profiler the MicroXAM-800 (**Figure 1c**) with x5 objective. Three lines from surface topography in direction of shaft axis were utilized for analysis of the roughness parameters.

a)
b)
c)

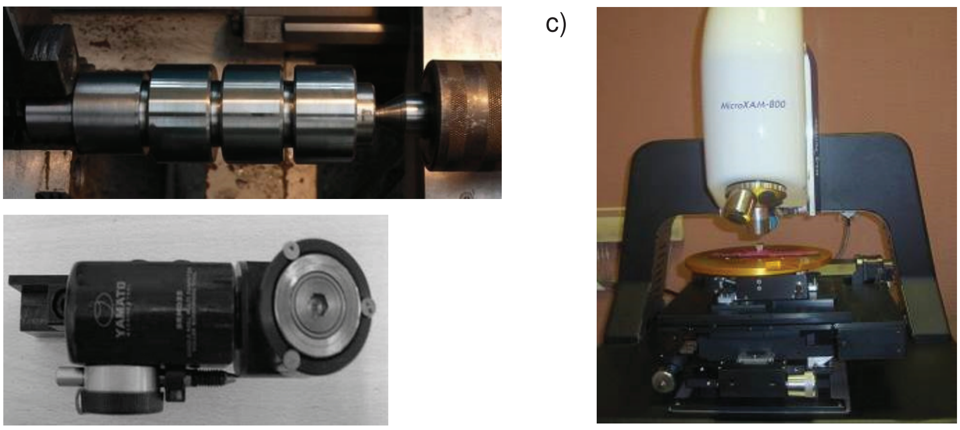


Figure 1 a) Sample used in the research b) burnishing tool c) MicroXAM-800

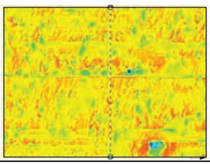
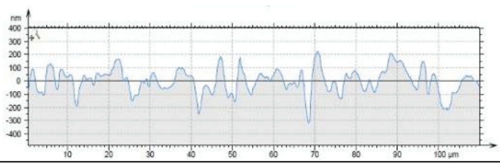
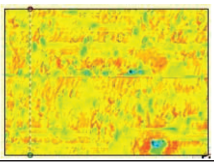
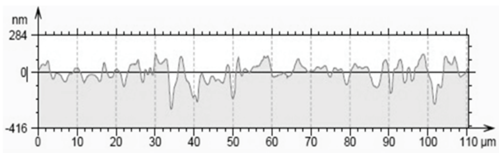
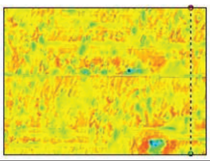
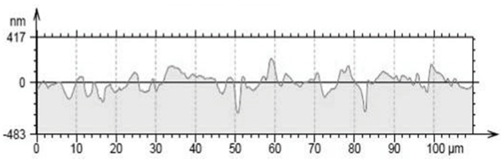
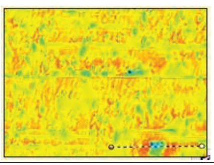
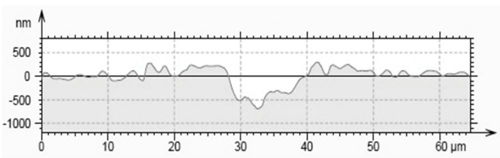
Table 1 Technological parameters of burnishing process

Parameters	Values	Parameters	Values
Burnishing force - F [kN]	1.1	Feed - f [mm/rev]	0.08
Burnishing speed - V_n [m/min]	35	Number passes of burnishing tool	1, 2, 3, 4

3. RESEARCH RESULTS

Tables 2 - 5 show the profile of roughness in the three measuring lines of the analyzed surface topography. In these tables are shown the results of measurements of the surface roughness profile curves such as Ra, Rq, and Rz. In addition, for each of the analyzed surface of shaft pins defined the biggest loss in the surface layer, which is also illustrated in the profile of surface roughness. Surface of shaft after burnishing process, taking into account a one pass of burnishing tool (**Table 2**) is characterized by the average value of surface roughness equal respectively: Ra = 54.2 nm, Rq = 71.5 nm and Rz = 332 nm. For the obtained surface topography can be observed the local defects of the surface layer, and the biggest of them is shown in the last profile curve of surface roughness amounted to nearly 900 nm.

Table 2 The surface topography, surface profile analysis and parameters of surface roughness for shaft after 1 pass of burnishing tool

Surface topography	Profile curve	Parameters of surface roughness [nm]
		Ra = 62.5 Rq = 82.5 Rz = 430
		Ra = 45.8 Rq = 60.4 Rz = 298
		Ra = 54.3 Rq = 71.6 Rz = 368
		View of surface defect

Burnishing process takes into account two passes of burnishing tool allowed to obtain the average values of roughness parameters analyzed at a level equal to: Ra = 71.2 nm , Rz = 92.0 nm and Rq = 455 nm (**Table 3**). While the shaft surface after three passes of burnishing tool is characterized by the average values of the analyzed parameters roughness equal: Ra = 83.4 nm, Rq = 104.7 nm and Rz = 490 nm (**Table 4**). The biggest defects on shaft surface after burnishing process was carried out with two and three passes of burnishing tool shown in the last profiles of surface roughness. Defects surface layer analyzed for surface topography have reached the level of 800 and 600 nm.

Table 3 The surface topography, surface profile analysis and parameters of surface roughness for shaft after 2 passes of burnishing tool

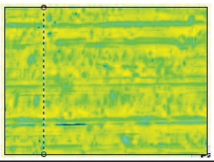
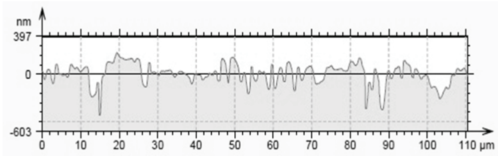
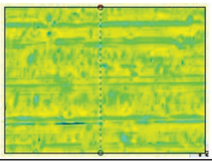
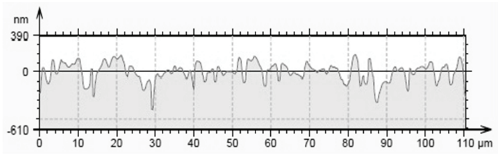
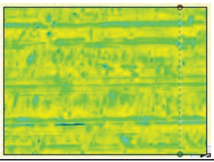
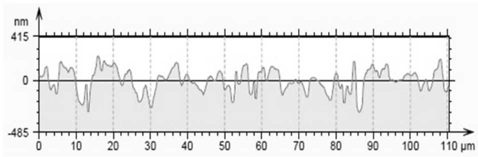
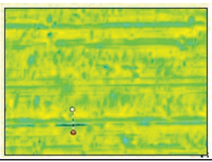
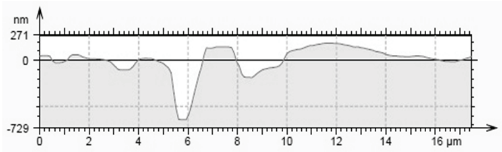
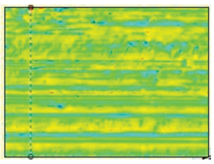
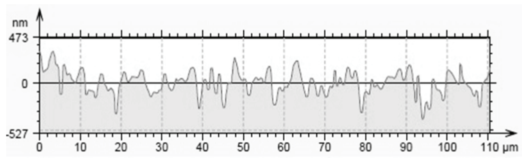
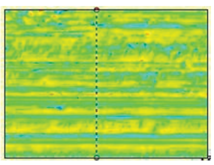
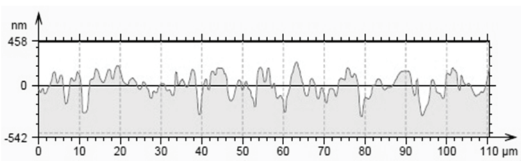
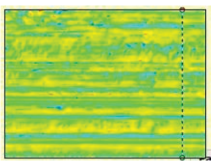
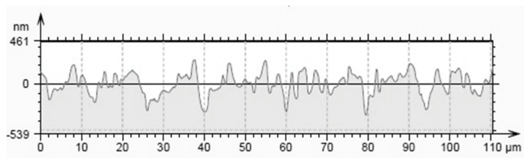
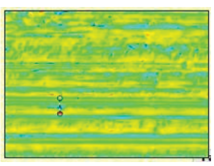
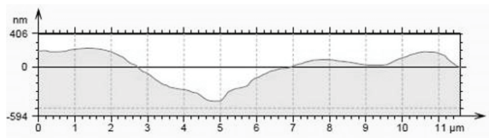
Surface topography	Profile curve	Parameters of surface roughness [nm]
		Ra = 71.3 Rq = 94.0 Rz = 487
		Ra = 65.8 Rq = 86.6 Rz = 432
		Ra = 76.6 Rq = 95.5 Rz = 446
		View of surface defect

Table 4 The surface topography, surface profile analysis and parameters of surface roughness for shaft after 3 passes of burnishing tool

Surface topography	Profile curve	Parameters of surface roughness [nm]
		Ra = 80.9 Rq =102 Rz = 497
		Ra = 81.3 Rq = 100 Rz = 444
		Ra = 87.9 Rq =112 Rz = 529
		View of surface defect

Surface of shaft pin after burnishing process, taking into account the four pass of burnishing tool has an average value of roughness parameters equal, respectively: Ra = 88.7 nm, Rq = 112 nm and Rz = 504.7 nm. For the obtained surface topography can be observed the local defects of the surface layer, and the biggest of them was on the depth equal 750 nm.

Table 5 The surface topography, surface profile analysis and parameters of surface roughness for shaft after 4 passes of burnishing tool

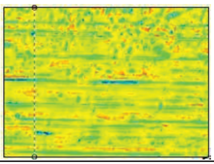
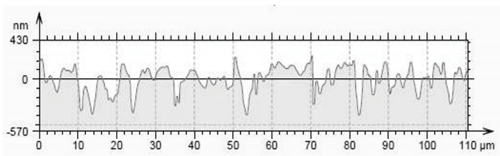
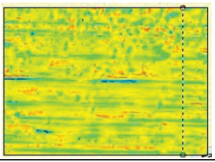
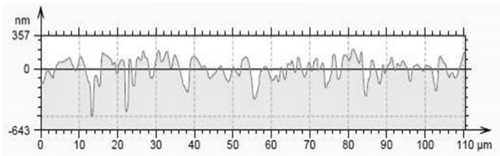
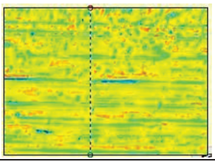
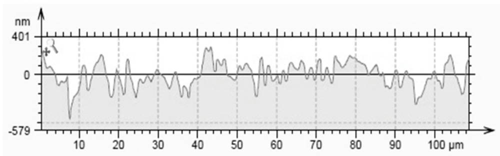
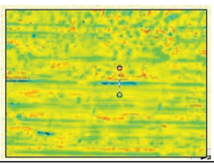
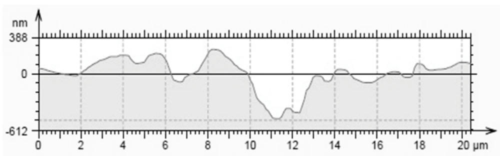
Surface topography	Profile curve	Parameters of surface roughness [nm]
		Ra = 98.5 Rq = 126 Rz = 600
		Ra = 93 Rq = 118 Rz = 522
		Ra = 74.6 Rq = 91.9 Rz = 392
		View of surface defect

Figure 2 shows a view of the surface topography of shaft pins after carried out of burnishing process, taking into account the 1, 2, 3 and 4 passes of burnishing tool.

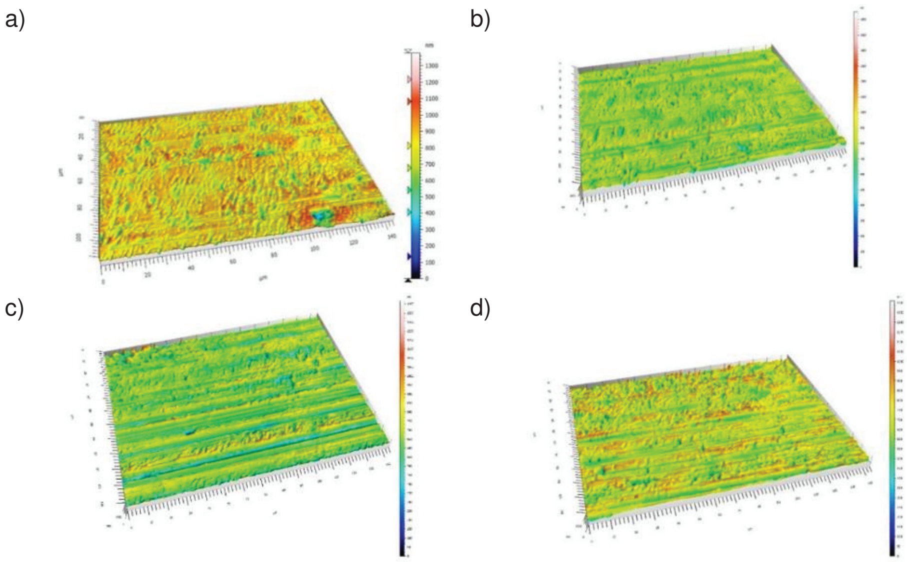


Figure 2 The view of surface topography for shaft after a) 1 pass of burnishing tool b) 2 passes of burnishing tool c) 3 passes of burnishing tool d) 4 passes of burnishing tool

Table 6 shows the results of measurements of the surface topography parameters SaR, SqR and SzR. The obtained results of measurements of the parameters analyzed coincide with the parameter values for the measurement 2D. The surface of the smallest values of the parameters of surface topography obtained after the first pass of burnishing tool. Additional burnishing process does not affect beneficial for smoothing the tops of surface roughness.

Table 6 Parameters of surface topography

Number passes of burnishing tool	Parameters of surface topography		
	SaR [nm]	SqR [nm]	SzR [nm]
1	86.6	285.9	206.0
2	88.6	471.3	227.8
3	79.6	481.2	212.2
4	101.3	483.4	207.3

4. CONCLUSION

One of the basic aims of burnishing process is smoothness treatment that reduces surface roughness after treatment prior to the process. After the preliminary turning on the surface of shaft pins, was obtain mean value of surface roughness Ra = 880 nm. Burnishing process was performed taking into account the additional passes of burnishing tool should additional smoothing the tops of surface roughness [8]. The measurement results of the topography and surface roughness parameters do not confirm of this relation. Measurements carried out at the micro- and nanoscale, allowed to observe the improvement of surface roughness in 16.2 times to Ra = 54.2 nm for the process of burnishing after one pass burnishing tool. Second, third and forth passes of burnishing process influence on surface topography but does not visible affect on roughness parameters that can be described by restructuring of surface layer. Research of marine pump shaft pins will be subject to the measurement of roughness parameters and surface topography for macroscopic scale using contact T8000 stylus profilometer.

REFERENCES

[1] DYL, T., Finishing intermetallic coatings in order to reduce the surface roughness. *Journal of KONES Powertrains and Transport*, 2013, Vol. 20, no. 1, pp. 77-82.

[2] DYL, T., The finishing of composite coatings in aspect of surface roughness reduction. *Journal of KONES Powertrains and Transport,* 2013, Vol. 20, no. 2, pp. 75 - 81.

[3] DYL, T., STAROSTA, R., Określenie wpływu geometrii i rodzaju materiału płytek skrawających na topografię toczonych powłok kompozytowych. *Inżynieria Materiałowa,* 2012, nr 6, pp. 701 - 704.

[4] DYL, T., STAROSTA, R., Wpływ geometrii i gatunku płytek skrawających na strukturę geometryczną toczonych powłok stopowych. *Inżynieria Materiałowa,* 2011, nr 4, pp. 395-398.

[5] LABUDA, W., CHARCHALIS, A. Ocena wpływu geometrii noża tokarskiego na strukturę geometryczną powierzchni czopów wałów wykonanych ze stali austenitycznej. *Logistyka,* 2014, nr 6.

[6] LABUDA, W., The analysis of cutting tool geometric on cutting forces and surface roughness of steel applied to marine pumps shaft pins. *Journal of KONES Powertrains and Transport*, 2014, Vol. 21, no. 1, pp. 147 - 152.

[7] STAROSTA, R., DYL, T., Obróbka wykańczająca natryskiwanych płomieniowo powłok Ni-Al, ocena zużycia borazonowych płytek skrawających. *Tribologia. Teoria i Praktyka,* 2011, nr 4, pp. 245-252.

[8] CHARCHALIS, A., STAROSTA, R., LABUDA, W., Estimation of the influence of passes number burnishing tool on ships pumps shafts surface layers strengthening and roughness changes. *Journal of KONES Powertrain and Transport*, 2009, Vol. 16, no. 4, pp. 43-50.