THE INFLUENCE OF CUTTING PARAMETERS ON SURFACE ROUGHNESS PARAMETER OF STAINLESS STEEL AFTER FINISHING TURNING OF CCET09T302R-MF INSERT

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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 cutting parameters on surface roughness parameter of marine pump shaft. The turning process was carried out on a universal CDS6250BX-1000 centre lathe. The research was performed on a shaft made of X5CrNi18-10 (AISI 304L) stainless steel. During lathing process used DKM 2010 turning dynamometer. The finishing turning process was carried out by cutting tool with CCET09T302R-MF removable insert by DIJET. During turning the following machining parameters were used: cutting speed V_c = 226 m·min^{-1}, feed f = 0.044; 0.062; 0.083; 0.106 mm·rev^{-1} and cutting depth a_p = 0.25; 0.5; 0.75; 1.0 mm. The goal of the paper was to define the influence of treatment conditions on surface roughness parameter. The surface roughness parameter was measured by T8000 profilometer and the chemical composition of steel was measured by Solaris-ccd plus optical spectrometer.

Keywords: Finishing turning, surface roughness parameter, 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 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.

One of the most important stages of forecasting tasks for improving the quality of use of machinery and equipment is the development of methods to control their durable - reliable characteristics. The object must properly fulfill its tasks under certain conditions and time [1]. Research shows that nearly 80 % of the damage of machine parts has its beginning in the surface layer, and 50 % of the kinetic energy is lost to overcome the frictional resistance [2]. The manufacturing process of machine parts is related to formation of the technological surface layer.

Ensure appropriate design, materials and manufacturing technologies should provide the desired initial state of the workpiece [3, 4]. The most common and universal way to remove layers of abraded material is the cutting process.

For the basic method of the surface layer forming of shaft pins is known lathing. Conventional machining accuracy is usually considered as a function of the characteristics of all the components of machine tool, fixture, object and tool. There are: accuracy performance, and the accuracy of static and dynamic determining and cutting parameters, which are associated with strength, temperature and wear of the cutting edge. Therefore, stock removal of high efficiency should be performed in a controlled manner which ensures the correct shape and size of the chip.

Many scientific centres, including the Gdynia Maritime University, deal with issues related to the turning surface of the difficult-to-machine [5 ÷ 14]. The research aims to determine a set of input factors, fixed and distorting for the finish lathing of pins shafts made of stainless steel, had an impact on geometrical structure of the surface, as well as on the values of forces and cutting temperature. Machining stainless steels, especially austenitic steel, causes a lot of difficulties. On the machinability of austenitic steel has a negative impact high propensity to the deformation strengthening, low thermal conductivity and good ductility. Alloying element improves the machinability of stainless steels is sulphur. Sulphur in combination with manganese forms MnS manganese sulphide, which positive influence on machinability is confirmed by the type of chips (short and brittle), smoother surfaces of workpieces and less tool wear.

The article presents the preliminary results of influence of treatment conditions during turning of shafts on the surface roughness parameter.

2. RESEARCH METHODOLOGY

The research was performed on a shaft made of X5CrNi18-10 (AISI 304L) stainless steel (**Figure 1c**). The process of turning was carried out on a lathe CDS6250BX-1000 type (**Figure 1a**) by a cutting tool with removable insert CCET09T302R-MF type by DIJET. The cutting parameters used in the finish lathing process are presented in **Table 1**: cutting speed, feed and depth of cut. During cutting process DKM2010 turning dynamometer was used. DKM 2010 is a 5-components tool dynamometer for use on conventional or CNC lathe machines. It measures force on the cutting tool up to 2000 N with a resolution of 0.1 % and as option also temperature on the tool tip between 300 and 800 °C. DKM 2010 is equipped with adjustable inserts - holder to change entering angle $\varkappa_r$ into 45, 60, 70, 90°. The complete equipment of dynamometer is presented in **Figure 1b**.

a) b) c)

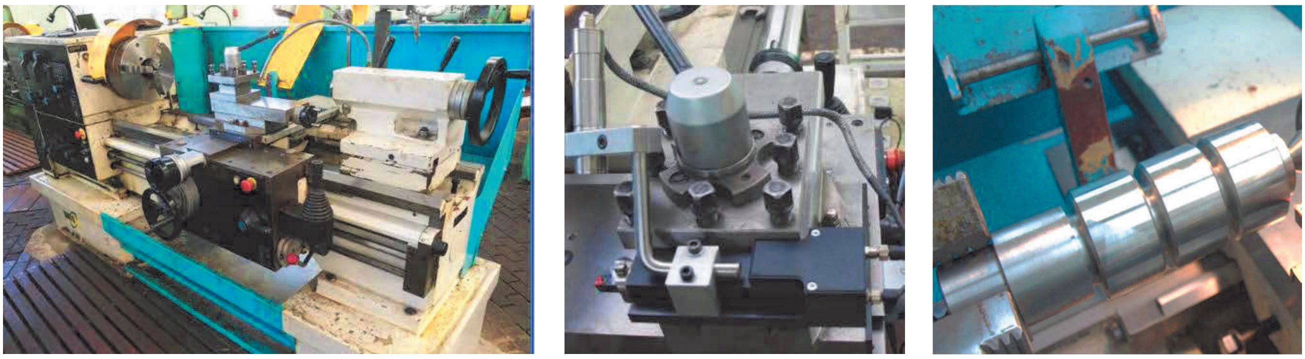

Figure 1 a) CDS 6250 BX-1000 lathe b) turning dynamometer c) sample used in the research

Table 1 Technological parameters of the cutting process

Shaft pins	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
Cutting speed Vc = 226 m·min⁻¹																
Depth of cut (mm)	*0.25*	*0.25*	*0.25*	*0.25*	*0.5*	*0.5*	*0.5*	*0.5*	*0.75*	*0.75*	*0.75*	*0.75*	*1.0*	*1.0*	*1.0*	*1.0*
Feed (mm·rev⁻¹)	*0.044*	*0.062*	*0.083*	*0.106*	*0.044*	*0.062*	*0.083*	*0.106*	*0.044*	*0.062*	*0.083*	*0.106*	*0.044*	*0.062*	*0.083*	*0.106*

Analysis of the chemical composition of the sample material was carried out on a Solaris-ccd plus spectrometer (**Figure 2 a**). It is an optical emission spectrometer with spark excitation by GNR. It performs the analysis of solid samples and metal alloys of different matrices. A percentage content of selected elements in steel was presented for sample after four spark test (**Figure 2 b**). The view of the shaft surface after the turning process was made on the Smartzoom 5 microscope (**Figure 2 c**).

a) b) c)

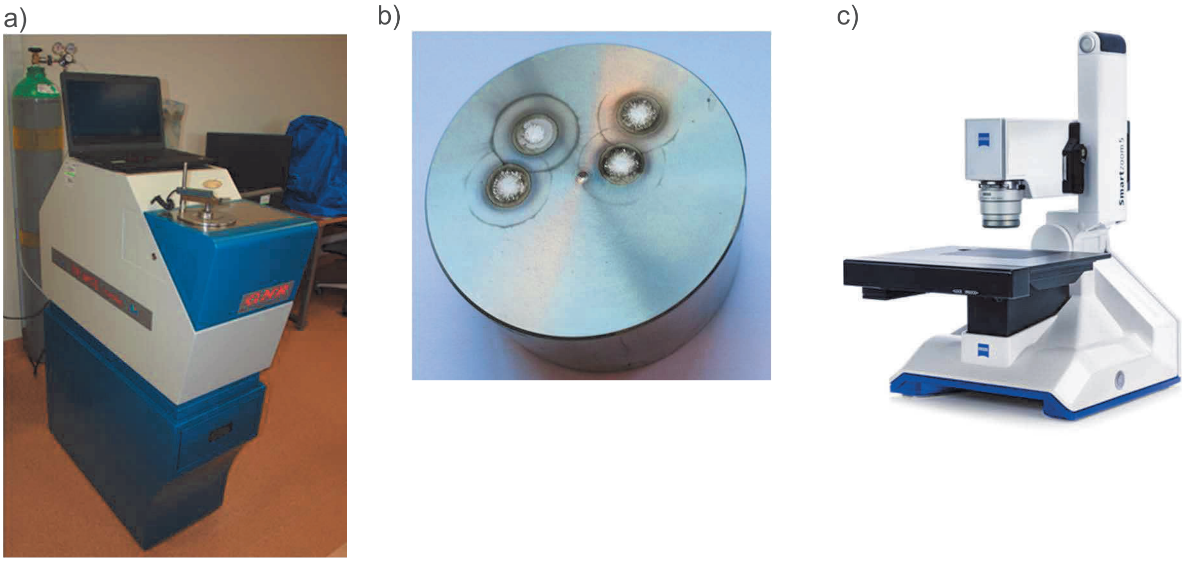

Figure 2 a) Solaris-ccd plus optical spectrometer b) the sample used for testing the chemical composition of the steel c) Smartzoom 5 microscope

3. RESEARCH RESULTS

The results of the chemical composition of steel X5CrNi18-10 are presents in **Table 2**.

Table 2 The results of the chemical composition of steel [%]

	C	Si	Mn	P	S	Cr	Mo	Ni	Nb
mean	0.037	0.457	1.638	0.028	0.030	18.261	0.473	7.760	0.008
max	0.057	0.478	1.659	0.030	0.033	18.332	0.482	7.847	0.010
min	0.025	0.440	1.612	0.026	0.028	18.164	0.465	7.628	0.006
	Al	Cu	Co	B	Ti	V	W	Fe	
mean	0.003	0.483	0.125	0.002	0.026	0.057	0.021	70.594	
max	0.004	0.490	0.127	0.002	0.027	0.058	0.021	70.731	
min	0.002	0.471	0.124	0.001	0.023	0.057	0.020	70.482	

During the research conducted turning of the shaft with a constant cutting speed Vc = 226 m·min^{-1}. The results of statistic analysis of surface roughness parameter were presented in **Table 3**. The lowest mean value of roughness parameter (Ra = 0.80 μm) after turning process was obtained on the shaft pin using cutting parameters: a_p = 0.5 mm and f = 0.062 mm·rev^{-1}. The biggest mean value of roughness parameter (Ra = 6.38 μm) was obtained for cutting parameter: a_p = 1 mm and f = 0.062 mm·rev^{-1}. The most preferred treatment conditions for the obtained value of the parameter Ra obtained for depth of cut: a_p = 0.25, 0.5, 0.75 and 1.0 mm and value of feed equal 0.044 mm·rev^{-1}. Value of the parameter Ra at the same level obtained for the depth of cut a_p = 0.25 ÷ 0.75 mm and feed equal 0.062 mm·rev^{-1}.

Table 3 The results of statistical analysis of surface roughness parameter Ra

No of shaft pins	Cutting parameters		Ra parameter (μm)				
	a_p (mm)	F (mm·rev^{-1})	Mean	Minimum	Maximum	Stand. dev.	Stand. error
1	0.25	0.044	0.82	0.77	0.92	0.06	0.03
2	0.25	0.062	0.97	0.82	1.16	0.15	0.07
3	0.25	0.083	2.09	1.90	2.41	0.20	0.09
4	0.25	0.106	1.91	1.85	1.97	0.05	0.02
5	0.50	0.044	0.88	0.84	0.93	0.04	0.02
6	0.50	0.062	0.80	0.74	0.84	0.04	0.02
7	0.50	0.083	2.20	1.63	3.05	0.57	0.25
8	0.50	0.106	3.75	3.07	4.28	0.44	0.20
9	0.75	0.044	0.85	0.80	0.90	0.04	0.02
10	0.75	0.062	0.89	0.81	0.96	0.07	0.03
11	0.75	0.083	1.30	1.24	1.37	0.07	0.03
12	0.75	0.106	2.35	1.98	2.92	0.39	0.18
13	1.00	0.044	0.94	0.80	1.08	0.13	0.06
14	1.00	0.062	6.38	3.89	10.03	2.32	1.04
15	1.00	0.083	4.77	3.19	7.24	1.61	0.72
16	1.00	0.106	3.00	2.96	3.12	0.07	0.03

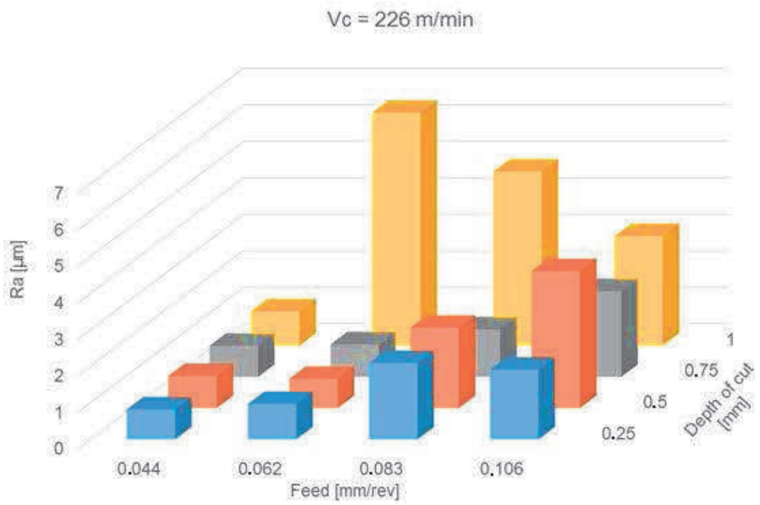

Figure 3 The influence of cutting parameters on surface roughness parameter Ra (μm)

The application of different cutting parameters for the turning process has a significant influence on the mean values of the surface roughness parameter of shaft surface. The influence of change of cutting parameters on surface roughness parameter Ra is presented in **Figure 3**.

The best operating range of the cutting insert can be observed for a feed f = 0.044 mm·rev^{-1} for all range cutting depth and for a feed f = 0.062 mm·rev^{-1} in the cutting depth range between 0.25 to 0.75 mm. Despite obtaining approximate values Ra parameter on the surface of the shaft pins were observed significant tool marks after turning process. **Figure 4** presents the examples of shaft surface profile analysis for different depth of cut and feed equal 0.062 mm·rev^{-1}. The apex distribution of individual surface profiles differs from one another, which demonstrates the varied quality of the surface treated. **Figure 5** shows the surface view for the same shaft pins for which was observed surface profile. This figure shows a surface view of the shaft pins after turning with a feed 0.062 mm·rev^{-1} and a cutting depth between 0.25 to 1.00 mm. While **Figure 6** shows a view of the surface of shaft pins after turning process with a feed equal 0.044 mm·rev^{-1}. On the surface of the shaft pins we can observe furrows and even the spalling of material of surface layer.

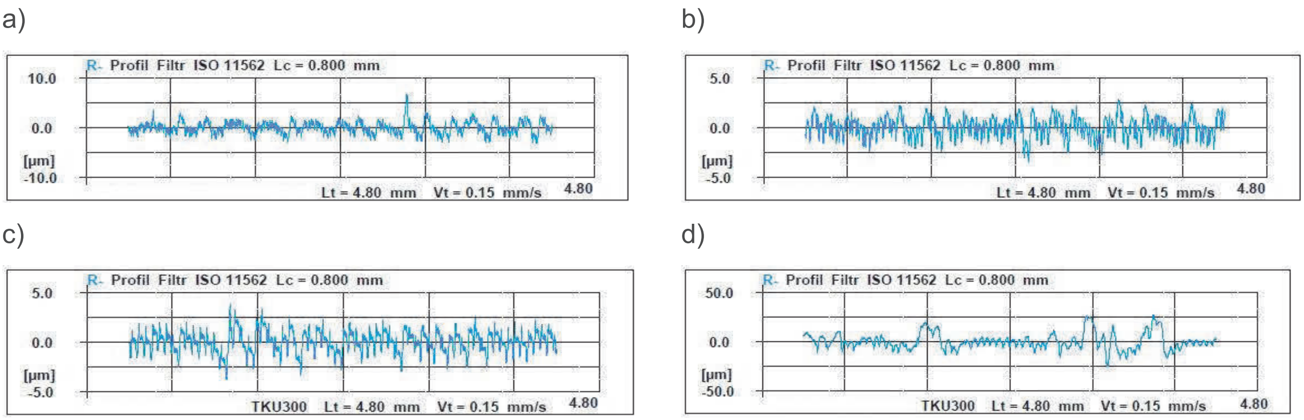

Figure 4 The examples of shaft surface profile analysis for depth of cut: a) a_p = 0.25 mm b) a_p = 0.5 mm c) a_p = 0.75 mm d) a_p = 1.0 mm

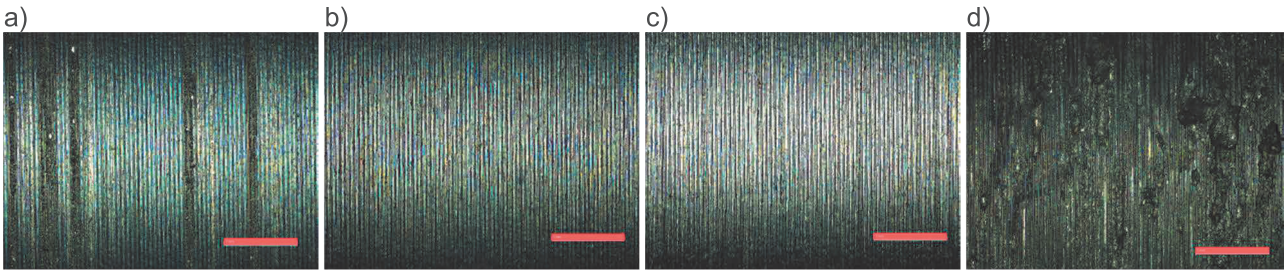

Figure 5 The shaft surface after turning process for depth of cut: a) a_p = 0.25 mm b) a_p = 0.5 mm c) a_p = 0.75 mm d) a_p = 1.0 mm

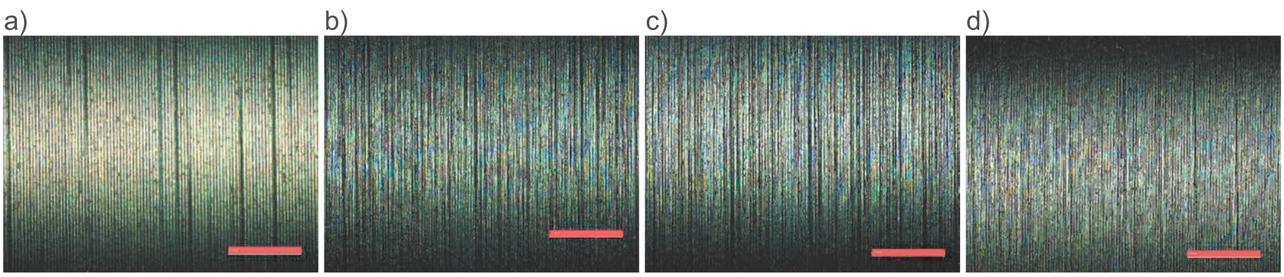

Figure 6 The shaft surface after turning process for feed = 0.044 mm·rev^{-1} and depth of cut: a) a_p = 0.25 mm b) a_p = 0.5 mm c) a_p = 0.75 mm d) a_p = 1.0 mm

4. CONCLUSION

The article is one of a series of publications relating to define a set of input factors, fixed and disruptive on the process of finishing turning shaft pins made of stainless steel. Machining of stainless steels is classified as a difficult-to-machining steel. Therefore, in order to ensure of appropriate the quality of surface roughness and productivity, it should be provide the most favorable treatment conditions during processing.

Analysis of the test results enables the selection of cutting parameters for the CCET09T302R-MF insert for which the Ra surface roughness values obtained will be less than 1µm. Machining process of the shafts surface could cause cutting furrows and spalling of material of surface layer, which negatively influence on the quality of the surface.

The aim of determining in detail the influence of cutting parameters on the geometric structure of surface, an analysis of other surface roughness and material ratio will be performed. Additionally, the research results of the influence of treatment conditions on the cutting forces of shaft pins will be done. The multiple regression equations for both surface roughness and cutting forces will also be determined. The final step of research will be comparing the results obtained in 2D measurements with measurements of the surface topography.

REFERENCES

[1] SZCZEREK, M., WIŚNIEWSKI, M., *Tribologia i Tribotechnika*. Wydawnictwo Instytutu Technologii Eksploatacji, 2000, Radom.

[2] SZYC, M., BARTOSIK, P., KUKIEŁKA, L., *Komputerowe modelowanie i symulacja stanów deformacji w warstwie wierzchniej wyrobów kulowanych*, Współczesne problemy w technologii obróbki przez nagniatanie, , Wydawnictwo Politechniki Gdańskiej, 2008, Vol 2, pp. 249 ÷ 254.

[3] BURAKOWSKI, T,. MARCZAK, R., Eksploatacyjna warstwa wierzchnia i jej badanie. Zagadnienia Eksploatacji Maszyn, 1995, no. 3, pp. 327 ÷ 337.

[4] BURAKOWSKI, T., MARCZAK, R., SENATORSKI, J., SZUMNIAK, J., Konstytuowanie eksploatacyjne warstwy wierzchniej w procesie tarcia technicznie suchego. Problemy Eksploatacji, 1998, no. 2, pp. 5 ÷ 36.

[5] 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.

[6] DUDZIK, K., The influence of welding parameters on the quality of joints made by FSW of AW-5083 aluminium alloy. In *METAL 2016: 25th Anniversary International Conference on Metallurgy and Materials*. Ostrava: TANGER, 2016, pp. 694-699.

[7] DUDZIK, K., JURCZAK W., Influence of friction stir welding (FSW) on mechanical and corrosion properties of AW-7020M and AW-7020 alloys, Polish Maritime Research, 2016, Vol.23, No. 3 (91), pp. 86-90.

[8] 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.

[9] 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.

[10] DYL, T., STAROSTA, R., Określenie wpływu geometrii i rodzaju materiału płytek skrawających na topografię toczonych powłok kompozytowych. *Inżynieria Materiałowa,* 2012, no 6, pp. 701 - 704.

[11] DYL, T., STAROSTA, R., Wpływ geometrii i gatunku płytek skrawających na strukturę geometryczną toczonych powłok stopowych. *Inżynieria Materiałowa,* 2011, no 4, pp. 395-398.

[12] LABUDA, W., CHARCHALIS, A. Ocena wpływu geometrii noża tokarskiego na strukturę geometryczną powierzchni czopów wałów wykonanych ze stali austenitycznej, 2014, *Logistyka,* no 6.

[13] 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.

[14] 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.