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THE INFLUENCE OF CHANGING THE SIDE ANGLE OF THE CUTTING TOOL BY WIPER TECHNOLOGY ON THE VALUE OF MATERIAL RATIO PARAMETERS OF STEEL APPLIED TO MARINE PUMP SHAFT PINS

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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 firefighting 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 take place. The research attempts to increase the service life of shafts.

The article presents the research results of pump shaft pins after finish lathing. The research was performed on a roller 60 mm in diameter made of X5CrNi18-10 steel. The finish tooling of pump shaft pins was carried out on a universal CDS 6250 BX-1000 centre lathe. The finish lathing process was carried out by means of Sandvik Coromant cutting tool with replaceable inserts. In the research of lathing, process used inserts with Wiper technology. During the lathing, the optimal cutting parameters were used for inserts: CCMT09T302WF, CCMT09T304WF and CCMT09T308WF. The cutting process was performed at side angle of 90° ± 3°. The process of lathing used cutting tool dynamometer DKM 2010. During the research, the effect of cutting tool geometric on surface roughness parameter R_a of steel applied to marine pumps shaft pins was determined. The article presents the research results of material ratio parameters. In addition provides an examples shaft surface profile analysis and material ratio. Measurement of surface roughness and material ratio parameters was performed by T8000 profilometer.

Keywords: *turning dynamometer, surface roughness, material ratio, stainless steal*

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 it 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 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.

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, tool. There is 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.

Machining stainless steels, especially austenitic steel, causes a lot of difficulty. 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.

During the implementation of the research work entitled "Assessment of suitability of burnishing process that improve operating properties of marine pump shafts" [6], the use of fixed parameters of preliminary machining technology, resulted in a variety of measurements of surface roughness examined shafts. The shaft pins ϕ39 mm in diameter, made of X5CrNi18-10 stainless steel was carried out on a universal CDS 6250 BX-1000 lathe centre. The preliminary lathing process was conducted by a cutting tool with WNMG080408WF removable inserts by Sandvik Coromant. During the lathing, the following cutting parameters were used: cutting speed V_c = 112 m/min, feed f = 0.13 mm/rev, cutting depth a_p = 0.5 mm. The statistic analysis results of the obtained values of roughness factor measurements were presented in Tab. 1. The correct effect in the machining result of burnishing process depends on the primarily geometry, surface condition and hardness burnishing tool. However, the important factor is also suitable preparation of the surface shafts before burnishing process.

Tab. 1. The results of statistic analysis of surface roughness parameter

Mean	Median	Minimum	Maximum	Stan. Deflection	Stan. Error
0.83	0.79	0.50	1.18	0.14	0.02

Many scientific centres, including the Gdynia Maritime University, deal with issues related to the turning surface of the difficult-to-machine [1-5, 7, 8]. 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. Article presents the research of the influence of changing the side angle of the cutting tool on the value of material ratio parameters of steel applied to marine pump shaft pins.

1. Research methodology

The process of finish machining of shaft pins ϕ60 mm in diameter (Fig. 1), made of X5CrNi18-10 stainless steel was carried out on a universal CDS 6250 BX-1000 centre lathe. The lathing process was conducted by a cutting tool with removable inserts. Cutting tool by Wiper technology are innovative high-productivity inserts for semi-finish and finish turning. Thanks to a subtle change to the insert nose radius the feed rates can be doubled without changing the surface finish, compared with conventional inserts. In contrast, using the same feed as the traditional inserts, allows obtaining the double lower value of the parameter surface roughness. Inserts used in the research occurred in three varieties nose radius $r_\varepsilon = 0.2$, 0.4, 0.8 mm. The lathing process was performed in range of side angle 90° ± 3°. Changing the side angle was accomplished by deflection of compound rest with accuracy at 1°. The cutting parameters were used in the finish lathing process are presents in Tab. 2: cutting speed V_c [m/min], feed f [mm/rev] and depth of cut a_p [mm]. During the research were used the cutting parameters recommended by the manufacturer of the tool. However, the cutting speed and feed have been selected by the possibility of adjusting the lathe. In addition, the effect of reducing the cutting speed on the analysed surface roughness parameters R_a for the inserts CCMT 09T308 WF. The shaft used in the research is presented in Fig. 1.

Tab. 2. The cutting parameters for the finish lathing process

Inserts code	Cutting parameters		
	V_c [m/min]	f [mm/rev]	a_p [mm]
CCMT 09T302 WF	230	0.099	0.3
CCMT 09T304 WF	230	0.198	1.0
CCMT 09T308 WF	160	0.248	1.0
CCMT 09T308 WF	113	0.248	1.0

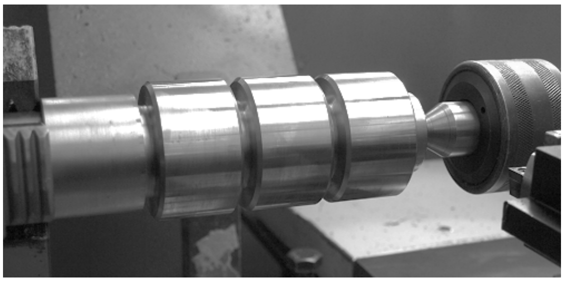

Fig. 1. Sample used in the research

Lathing process was carried out by turning dynamometer. 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 temperatures on the tool tip between 300 and 800 °C. DKM 2010 is equipped with adjustable inserts – holder to change side angle $\varkappa_r$ into 45, 60, 70, 90°. The complete equipment of DKM 2010 is presents in Fig. 2.

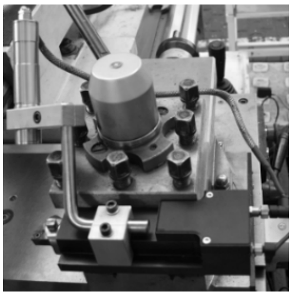

Fig. 2. Turning dynamometer

The surface roughness was measured by T8000 profilometer. In order to analyse the effect of geometry of inserts by Wiper technology on the resulting value of surface roughness was used parameter R_a (arithmetical mean deviation of the assessed profile). To analysis of the material ratio used following parameters such as: R_{pk} (reduced peak height), R_{vk} (reduced valley depth) and R_k (core roughness depth).

2. Research results

In Tab. 3-6, the results of the statistical analysis of the basic parameters of surface roughness and material ratio were presented. The average values were calculated from the results of 9 measurements of the surface shaft pins. The first column shows a value of side angle changes in range ± 3°. Side angle $\varkappa_r$ equal to 90° is marked value (0). Increase and decrease of side angle of the value 1 degree was carried out by deflection of compound rest.

In Tab. 3, the results of measurements of the surface of shaft pins turned off insert CCMT 09T302 WF were presented. The lowest value R_a = 0.69 µm was obtained for the side angle equal to 90°. Increase and decrease the angle of ±2° caused a slight increase for the parameter R_a. Change the value of the angle of -3° possible to obtain R_a = 1.16 µm and the value of R_a = 1.51 µm for the angle of 3°. Analysing the parameter of material ratio R_{pk} it can be seen that the vertices superfinishing surface unevenness occurred for the side angle of 90° and 91°. For other side angles of edge cutting tool by Wiper does not smoothest of surface unevenness vertices and the highest value R_{pk} = 5.00 µm with a standard deviation of 2.66 was obtained for the order of the angle $\varkappa_r$ equal 93°. The example shaft surface profile analysis and material ratio for inserts used in lathing process were presented in Fig. 3.

In Tab. 4, the results of measurements of the surface of shaft pins turned off insert CCMT 09T304 WF were presented. For finish lathing process with insert CCMT 09T304 WF lowest value of parameter R_a = 0.98 was obtained for the side angle equal to 93°. With decreasing of $\varkappa_r$ values is a marked increase in the value of the parameter R_a. R_{pk} parameter analysis showed that the greatest influence of geometry of insert by Wiper on the smoothness of the surface vertices was observed for the highest value side angle. The example shaft surface profile analysis and material ratio for inserts used in process were presented in Fig. 4.

In Tab. 5, the results of measurements of the surface of shaft pins turned off insert CCMT 09T308 WF for V_c = 160 m/min was presented. The use of optimum cutting parameters for lathing process with nose radius 0.8 mm allowed to obtain the smallest value R_a (1.75 µm) for the side angle equal 90°. Changing the position of the main cutting edge in the range of ±3° caused an increase in roughness of the analysed surface roughness parameter. Largest smoothing vertices of surface roughness (R_{pk} = 1.87 µm) was observed for increased $\varkappa_r$ angle equal 93°, for which the parameter R_a was 1.92 µm. The example shaft surface profile analysis and material ratio for inserts used in process were presented in Fig. 5.

In Tab. 6, the results of measurements of the surface of shaft pins turned off insert CCMT 09T308 WF for V_c = 113 m/min were presented. The example shaft surface profile analysis and material ratio for inserts used in process were presented in Fig. 6.

Decrease the cutting speed to 113 m/min allowed to obtain the lowest values of the surface roughness for side angel increased in the range of 1° to 3°. Surface roughness parameters achieved a value 1.47 and 1.48 µm. Decrease the $\varkappa_r$ angle caused an increase the value of the parameter R_a. The maximum value of the shaft surface roughness parameter obtained for a side angle of 87°, which was equal to 2.59 µm. For decreased value of the cutting speed by changing the side angle of the value of 2 and 3 degrees occurred a very marked increase in the value of the parameter R_{pk}, which reached a maximum value of 4.47 µm. Decrease of side angle of less than 90 degrees for cutting speeds equal to 113 m/min contributed to the creation on the surface of the shaft distinct cutting marks. Surface view of shaft pins obtained after the lathing process with the side angle of 87° is shown in Fig. 7. Therefore, in Tab. 6 presents the results only for the side angle in the range of 89-93°.

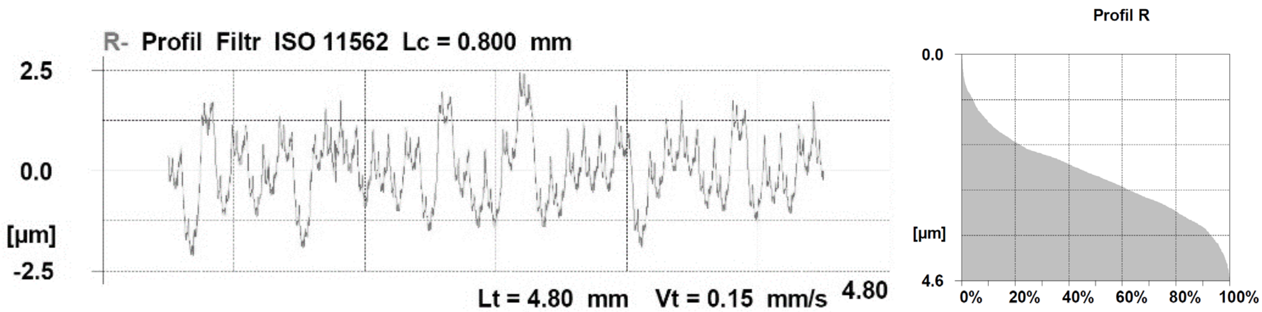

Fig. 3. The examples shaft surface profile analysis and material ratio for inserts CCMT 09T302 WF

Tab. 3. The results of statistical analysis of material ratio parameters for CCMT 09T302 WF insert

Change the value of side angle $\varkappa_r$ [°]	Mean	Minimum	Maximum	Stand. dev.	Stand. error
	R_a parameter [µm]				
-3	1.16	0.96	1.33	0.13	0.04
-2	0.80	0.67	1.10	0.13	0.04
-1	0.85	0.67	1.19	0.16	0.05
0	0.69	0.56	0.80	0.08	0.03
1	0.72	0.64	0.84	0.06	0.02
2	0.71	0.59	0.79	0.08	0.03
3	1.51	0.97	2.26	0.08	0.18
	R_{pk} parameter [µm]				
-3	1.76	0.99	2.56	0.48	0.16
-2	1.29	0.66	3.14	0.79	0.26
-1	1.73	0.74	3.19	0.83	0.28
0	0.72	0.49	1.06	0.18	0.06
1	0.80	0.48	1.34	0.27	0.09
2	1.62	0.47	2.95	0.95	0.32
3	5.00	1.43	7.71	2.66	0.89
	R_{vk} parameter [µm]				
-3	1.46	1.06	2.20	0.44	0.15
-2	1.06	0.74	2.25	0.45	0.15
-1	0.88	0.59	1.07	0.18	0.06
0	0.96	0.64	1.21	0.19	0.06
1	0.93	0.42	1.29	0.27	0.09
2	0.84	0.59	1.27	0.21	0.07
3	1.52	0.77	2.24	0.44	0.15
	R_k parameter [µm]				
-3	3.66	3.06	4.08	0.37	0.12
-2	2.47	2.05	3.04	0.28	0.09
-1	2.51	2.29	3.09	0.28	0.09
0	2.26	1.81	2.65	0.29	0.10
1	2.38	2.00	2.72	0.22	0.07
2	2.28	2.01	2.54	0.18	0.06
3	4.15	3.04	7.22	1.51	0.50

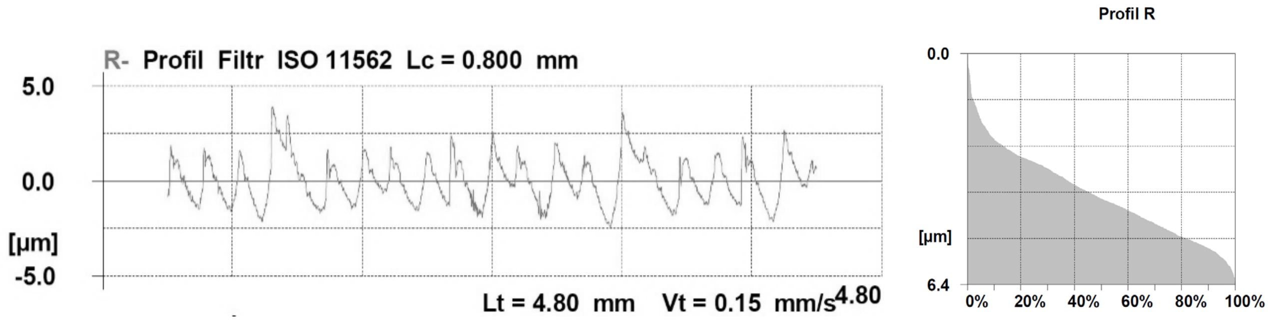

Fig. 4. The examples shaft surface profile analysis and material ratio for inserts CCMT 09T304 WF

Tab. 4. The results of statistical analysis of material ratio parameters for CCMT 09T304 WF insert

Change the value of side angle $\varkappa_r$ [°]	Mean	Minimum	Maximum	Stand. dev.	Stand. error
	R_a parameter [µm]				
-3	2.72	2.65	2.80	0.05	0.02
-2	2.50	2.42	2.59	0.06	0.02
-1	2.20	2.10	2.30	0.06	0.02
0	1.88	1.82	1.92	0.04	0.01
1	1.55	1.47	1.60	0.04	0.01
2	1.36	1.24	1.46	0.07	0.02
3	0.98	0.87	1.12	0.09	0.03
	R_{pk} parameter [µm]				
-3	3.77	3.20	4.34	0.38	0.13
-2	3.33	2.88	3.77	0.33	0.11
-1	2.24	1.95	2.99	0.35	0.12
0	2.12	1.85	2.49	0.19	0.06
1	1.56	1.31	1.84	0.16	0.05
2	1.32	1.05	1.70	0.27	0.09
3	0.92	0.60	1.37	0.29	0.10
	R_{vk} parameter [µm]				
-3	0.87	0.56	1.21	0.21	0.07
-2	0.78	0.38	1.43	0.39	0.13
-1	0.62	0.32	1.64	0.41	0.14
0	0.57	0.29	1.09	0.27	0.09
1	0.76	0.16	1.19	0.34	0.11
2	2.03	0.95	3.91	1.07	0.36
3	0.85	0.39	1.58	0.39	0.13
	R_k parameter [µm]				
-3	7.24	6.57	8.41	0.69	0.23
-2	6.63	5.76	7.46	0.70	0.23
-1	6.97	5.17	8.33	0.95	0.32
0	5.58	5.03	6.11	0.34	0.11
1	4.88	4.59	5.38	0.27	0.09
2	4.68	4.10	5.03	0.32	0.11
3	3.45	3.07	3.69	0.22	0.07

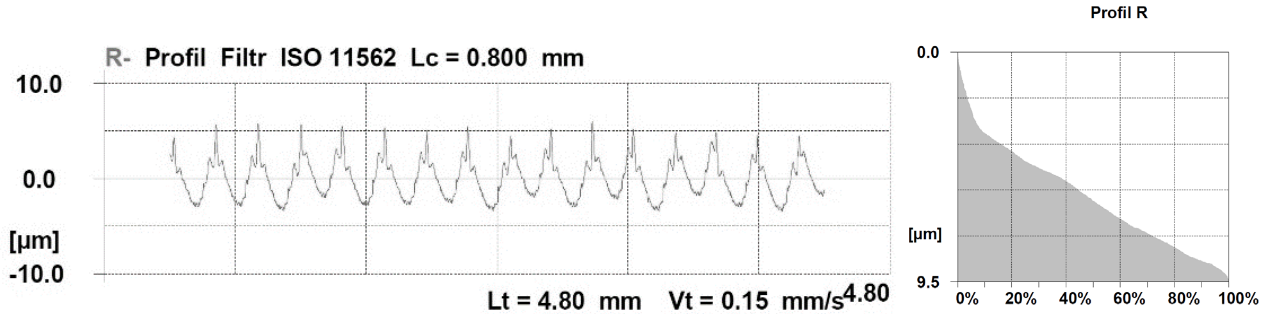

Fig. 5. The examples shaft surface profile analysis and material ratio for inserts CCMT 09T308 WF (V_c = 160 m/min)

Tab. 5. The results of statistical analysis of material ratio parameters for CCMT 09T308 WF insert (V_c = 160 m/min)

Change the value of side angle $\varkappa_r$ [°]	Mean	Minimum	Maximum	Stand. dev.	Stand. error
	R_a parameter [μm]				
-3	2.35	2.23	2.41	0.06	0.02
-2	2.14	2.02	2.35	0.10	0.03
-1	1.93	1.78	2.17	0.11	0.04
0	1.75	1.61	1.84	0.07	0.02
1	2.07	1.98	2.21	0.08	0.03
2	2.22	1.90	2.61	0.18	0.06
3	1.92	1.76	2.01	0.09	0.03
	R_{pk} parameter [μm]				
-3	4.66	4.16	5.16	0.40	0.13
-2	3.43	2.69	4.10	0.54	0.18
-1	2.22	1.67	3.04	0.44	0.15
0	2.25	1.71	2.96	0.39	0.13
1	2.51	1.86	3.29	0.44	0.15
2	3.43	2.83	4.78	0.58	0.19
3	1.87	1.32	2.23	0.25	0.08
	R_{vk} parameter [μm]				
-3	0.67	0.34	0.89	0.20	0.07
-2	1.19	0.43	2.55	0.68	0.23
-1	1.29	0.56	2.46	0.54	0.18
0	0.56	0.20	1.42	0.39	0.13
1	1.30	0.55	1.99	0.57	0.19
2	0.50	0.09	0.97	0.26	0.09
3	0.70	0.44	1.34	0.30	0.10
	R_k parameter [μm]				
-3	4.98	4.45	5.97	0.50	0.17
-2	6.10	5.41	7.00	0.53	0.18
-1	6.82	6.31	7.33	0.33	0.11
0	6.05	5.14	6.77	0.49	0.16
1	6.48	5.32	7.47	0.74	0.25
2	6.10	4.69	7.30	1.09	0.36
3	5.66	4.39	6.69	0.79	0.26

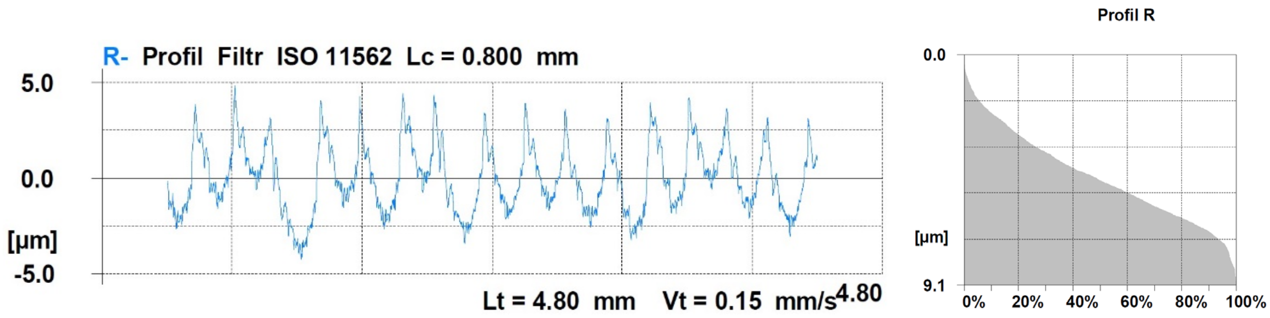

Fig. 6. The examples shaft surface profile analysis and material ratio for inserts CCMT 09T308 WF (V_c = 113 m/min)

Tab. 6. The results of statistical analysis of material ratio parameters for CCMT 09T308 WF insert (V_c = 113 m/min)

Change the value of side angle $\varkappa_r$ [°]	Mean	Minimum	Maximum	Stand. dev.	Stand. error
	R_a parameter [µm]				
-3	2.59	2.52	2.66	0.05	0.02
-1	2.42	2.26	2.76	0.20	0.07
0	1.79	1.61	1.95	0.13	0.04
1	1.47	1.28	1.77	0.13	0.04
2	1.47	1.34	1.60	0.10	0.03
3	1.48	0.97	2.11	0.35	0.12
	R_{pk} parameter [µm]				
-3	4.33	3.01	4.93	0.60	0.20
-1	2.47	2.11	2.97	0.31	0.10
0	2.15	1.49	3.86	0.68	0.23
1	1.87	1.38	2.79	0.45	0.15
2	4.20	3.21	5.75	0.90	0.30
3	4.47	2.41	6.52	1.33	0.44
	R_{vk} parameter [µm]				
-3	0.58	0.21	1.20	0.33	0.11
-1	1.78	0.41	3.54	1.03	0.34
0	0.96	0.27	1.78	0.49	0.16
1	1.24	0.79	1.76	0.35	0.12
2	1.09	0.43	1.73	0.37	0.12
3	1.58	1.28	1.95	0.24	0.08
	R_k parameter [µm]				
-3	6.24	5.47	8.03	0.86	0.29
-1	8.42	7.66	10.11	0.96	0.32
0	5.73	4.75	6.76	0.67	0.22
1	4.88	4.21	6.32	0.63	0.21
2	4.31	3.90	4.81	0.26	0.09
3	4.24	2.71	5.64	0.86	0.29

3. Conclusions

Finishing lathing of marine pump shaft pins made of stainless steel X5Cr-Ni18-10 with the use of inserts by Wiper technology allowed to get different values of analysed parameters of material ratio and parameters of surface roughness. Detailed analysis of such parameters allows precise

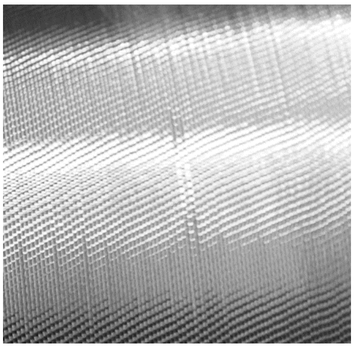

Fig. 7. View of surface after lathing process with side angle to 87°

analysis of the influence of geometry inserts, changing the side angle and cutting parameters on surface roughness smoothing the tops. Error of cutting tool settings with Wiper insert may be one of the factors disrupting the correct process of lathing steel used for marine pump shafts. The lowest values of R_a and R_{pk} parameters obtained for shafts after lathing with insert nose radius 0.2 mm. Application of Wiper inserts for lathing shaft pins subjected to regeneration in marine conditions may not achieve the appropriate cutting speeds. Conventional lathes used on ships may not possess relatively high ranges of rotational speed. Very important for the proper use of cutting edge by Wiper inserts is a precise positioning of the side angle of cutting tool.

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