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THE INFLUENCE OF TREATMENT CONDITIONS ON CUTTING FORCES AND SURFACE ROUGHNESS

Wojciech Labuda

Gdynia Maritime University, The Faculty of Marine Engineering
Morska Street 83, 81-225 Gdynia
tel.: +48586901549, Fax: +48586901399
e-mail: wlabuda@am.gdynia.pl

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 results of influence of treatment conditions during turning of shafts on the cutting forces and surface roughness parameter. A roller made of S235JR steel was used for the research. The cutting process was carried out on a universal CDS 6250 BX-1000 and CU500MRD centre lathes. Measurement of cutting forces during lathing process used DKM 2010 and Kistler turning dynamometers. The turning process was conducted by a cutting tool with CCMT09T304 PF removable plate. During the turning, the following machining parameters were used: cutting speed V_c = 150 m/min, feed f=0.106 mm/rev and cutting depth a_p = 0.5, 0.75, 1.0, 1.25, 1.5, 1.75 mm. The surface roughness was measured by T8000 profilometer.

Keywords: *turning dynamometer, surface roughness parameter, stainless steel*

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. Seawater 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 seawater 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 fulfil its tasks under certain conditions and time [11]. 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 [12]. 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 [1, 2]. The most common and universal way to remove layers of abraded material is the process of cutting.

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.

Many scientific centres, including the Gdynia Maritime University, deal with issues related to the turning surface of the difficult-to-machine [3-10]. 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 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.

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

1. Research methodology

During the research forces of cutting the shafts made of structural steel at normal quality was used. The process of turning was carried out on a universal CDS 6250 BX-1000 and CU500MRD lathe centres (Fig. 1). The lathing process was conducted by a cutting tool with CCMT09T304 PF removable plates. During the lathing, the following machining parameters were used: cutting speed V_c = 150 m/min, feed f = 0.106 mm/rev and cutting depth a_p in the range 0.5-1.75 mm.

a) b)

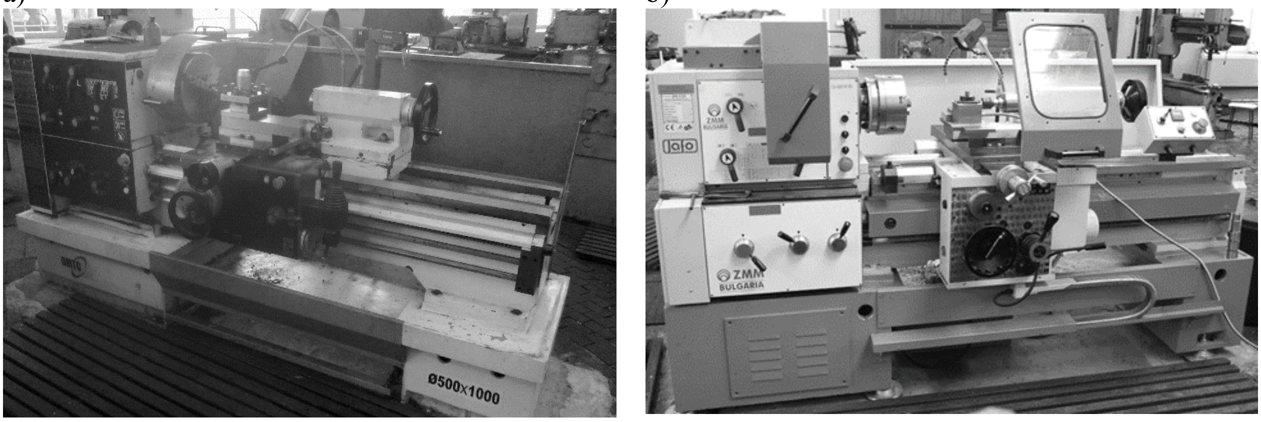

Fig. 1. Lathe type: a) CDS 6250 BX-1000 b) CU500MRD

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 entering angle $\varkappa_r$ into 45, 60, 70, 90°. The complete equipment of DKM 2010 is presented in Fig. 2a. The dynamometer was used on a lathe by CDS 6250 BX-1000 type.

Tool dynamometer by Kistler (Fig. 2b) can be use also on conventional or CNC lathe machines. It is a device that uses piezoelectric measuring method. Measuring chain consists of piezoelectric dynamometer (type 9119AA2), connecting cable and multichannel charge amplifier (type 5070) as well as a data acquisition and analysis system (DynoWere). The dynamometer is used for dynamic and quasistatic measurements of the 3 orthogonal components of any forces acting on the cover plate (F_x, F_y and F_z). The dynamometer measures the active force, irrespective of its application point. The dynamometer, during turning enables the measurement of force not exceeding the value of 2 kN. The dynamometer was used on a lathe by CU500MRD type.

a) b

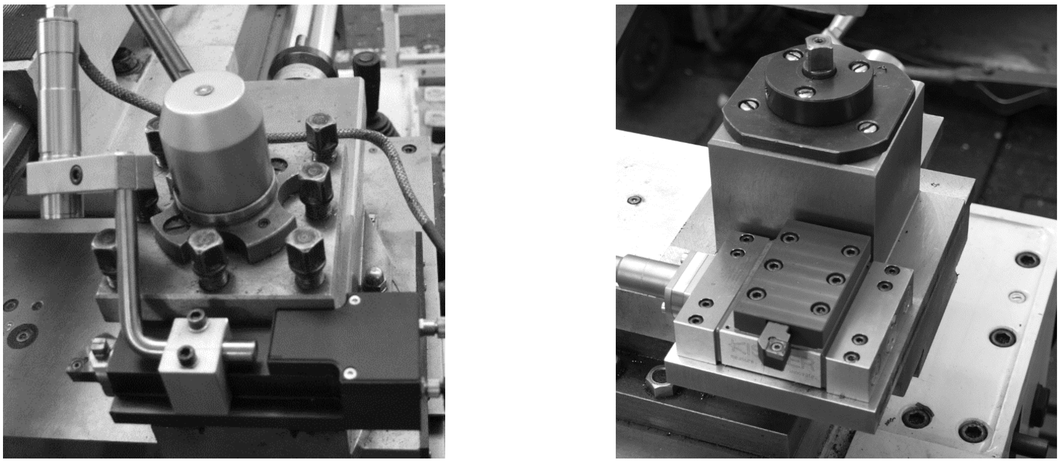

Fig. 2. Turning dynamometer a) DKM2010 b) Kistler

The surface roughness was measured by T8000 profilometer. For the measurements used measuring tip with a radius equal 2 µm. The analysis covered the parameter of surface roughness Ra (arithmetic mean deviation of the assessed profile).

2. Research results

In the research used the CCMT09T304 PF plate, which allows turning the depth of cut in the range from 0.11 to 2 mm. During the research conducted turning of the shaft with a depth of cut a_p = 0.50, 0.75, 1.00, 1.25, 1.5 and 1.75 mm. The turning process was carried out without cooling.

Figure 3 shows the effect of depth of cut on the change in the value of cutting force (F_c), feed force (F_f) and radial force (F_p). The results of statistic analysis for forces were presented in Tab. 1. The table presents mean values for cutting process include only the period of continuous operation of insert.

Tab. 1. The results of statistic analysis of cutting forces for DKM 2010 turning dynamometer

Depth of cut [mm]	F_c [N]			F_f [N]			F_p [N]		
	Mean	Stand. Dev.	Stand. Error	Mean	Stand. Dev.	Stand. Error	Mean	Stand. Dev.	Stand. Error
0.50	308	9.5	0.5	142	6.0	0.3	158	8.7	0.5
0.75	402	10.4	0.5	217	5.6	0.3	133	4.5	0.2
1.00	494	13.8	0.7	291	9.2	0.5	119	9.1	0.5
1.25	614	12.1	0.6	392	7.6	0.4	84	6.7	0.4
1.50	717	18.3	1.0	486	16.8	0.9	69	13.4	0.7
1.75	805	11.8	0.6	562	9.4	0.5	19	7.9	0.4

Analysis of influence changes of the cut depth on cutting forces showed that with increasing the value of a_p is an increase in the cutting force and feed force. Changing the depth of cut of 0.25 mm cause an average increase in force F_c and F_f the value between 75-115 N. At the same time, increasing the value of the parameter a_p leads to decrease in the value of the radial force. The highest values of F_c and F_f forces were obtained for a_p = 1.75 mm. The lowest value of F_p force was obtained for the same depth of cut. The greatest value of the standard deviation obtained for the depth of cut equal to 1.5 mm, which can provide the lowest stability of the cutting tool.

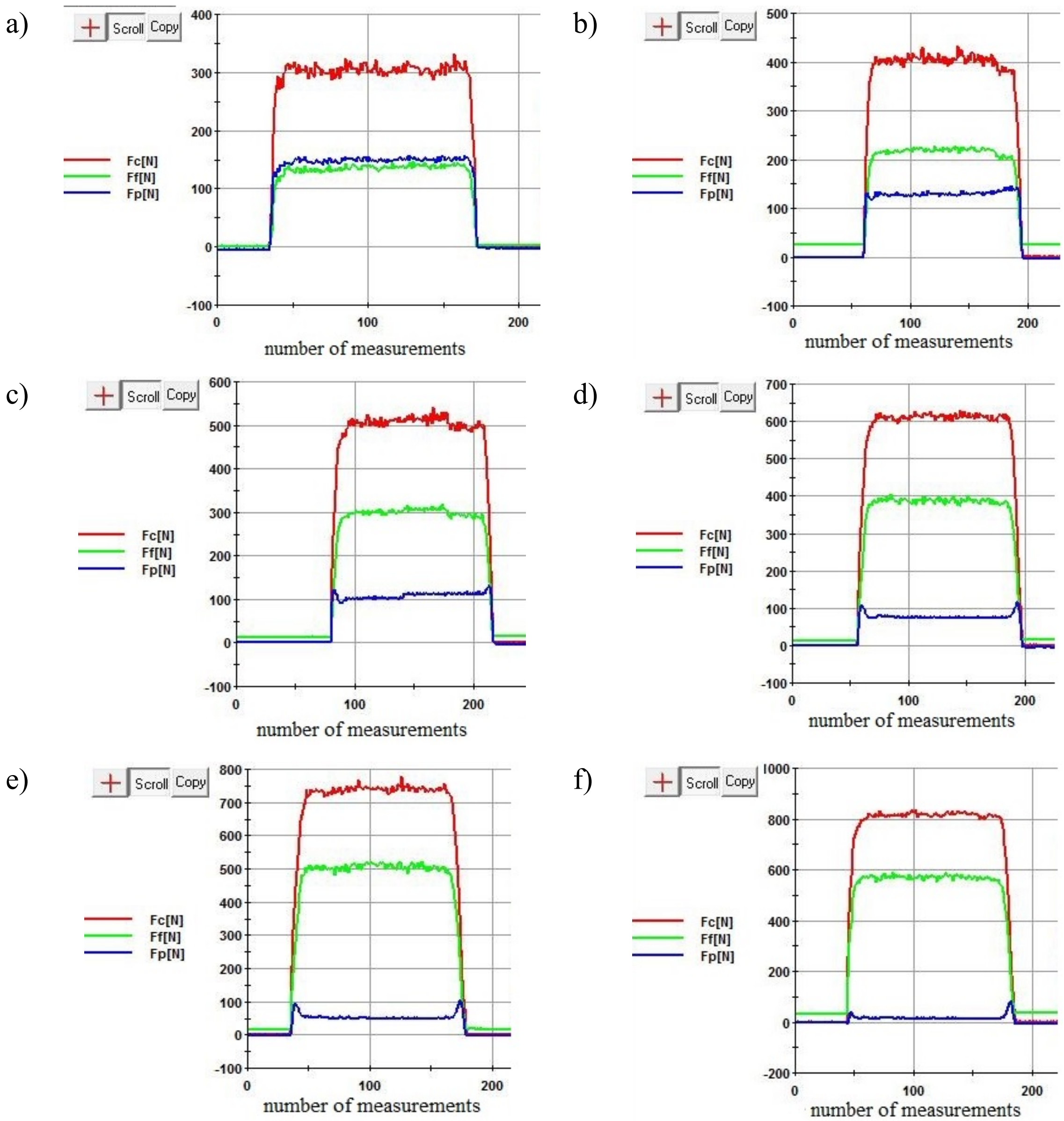

Fig. 3. Turning dynamometer DKM2010 – cutting forces for depth of cut a) a_p = 0.50 mm, b) a_p = 0.75 mm, c) a_p = 1.00 mm, d) a_p = 1.25 mm, e) a_p = 1.50 mm, f) a_p = 1.75 mm

Figure 4 presents the influence of changes of the depth of cut on the value of forces during the turning process. During turning operations recorded cutting force (F_z), feed force (F_y) and radial force (F_x). The charts show the full course of the cutting process, for which the total processing time of a single shaft pin was around 35 seconds. However, Tab. 2 shows the average measured values of forces for the cutting time equal to 25 seconds. This analysis include the period of continuous processing of the material, which does not take into account the input of the turning tool in the turning material and the moment output from the surface of the machined shaft.

Tab. 2. The results of statistic analysis of cutting forces for Kistler turning dynamometer

Depth of cut [mm]	F_z [N]			F_y [N]			F_x [N]		
	Mean	Stand. Dev.	Stand. Error	Mean	Stand. Dev.	Stand. Error	Mean	Stand. Dev.	Stand. Error
0.50	176.7	17.67	0.04	131.2	15.98	0.03	81.6	10.60	0.02
0.75	267.6	18.20	0.04	234.3	16.24	0.03	89.4	11.27	0.02
1.00	356.4	14.93	0.03	320.7	10.12	0.02	81.5	11.31	0.02
1.25	461.5	30.14	0.06	425.0	20.89	0.04	75.4	20.84	0.04
1.50	539.3	24.07	0.05	529.5	21.58	0.04	87.0	15.17	0.03
1.75	611.9	21.98	0.04	605.1	19.13	0.04	59.2	13.77	0.03

The lowest average value of cutting force (176.7 N) obtained during the turning of the depth of cut of 0.5 mm. Increasing of the a_p parameter of a further 0.25 mm causes as the constant increase of the analysed cutting forces. The largest value of this force (611.9 N) was obtained for the maximum depth of cut equal to 1.75 mm. A similar increase in the average value can be observed for the feed force. With the increase of cutting depth is an increase of force F_y. The maximum value of this force (605.1 N) was obtained for a_p = 1.75 mm. While increasing of the depth of cut has not resulted in significant changes of radial force. Mean values of F_x ranged between from 59.2 to 89.4 N, and the lowest value was for the process of turning with a_p = 1.75 mm. The largest dispersion between the minimum and maximum forces can be observed to a depth of cut equal to 1.25 mm. The obtained mean value of the standard deviation for the depth of cut shows the least stable cutting process.

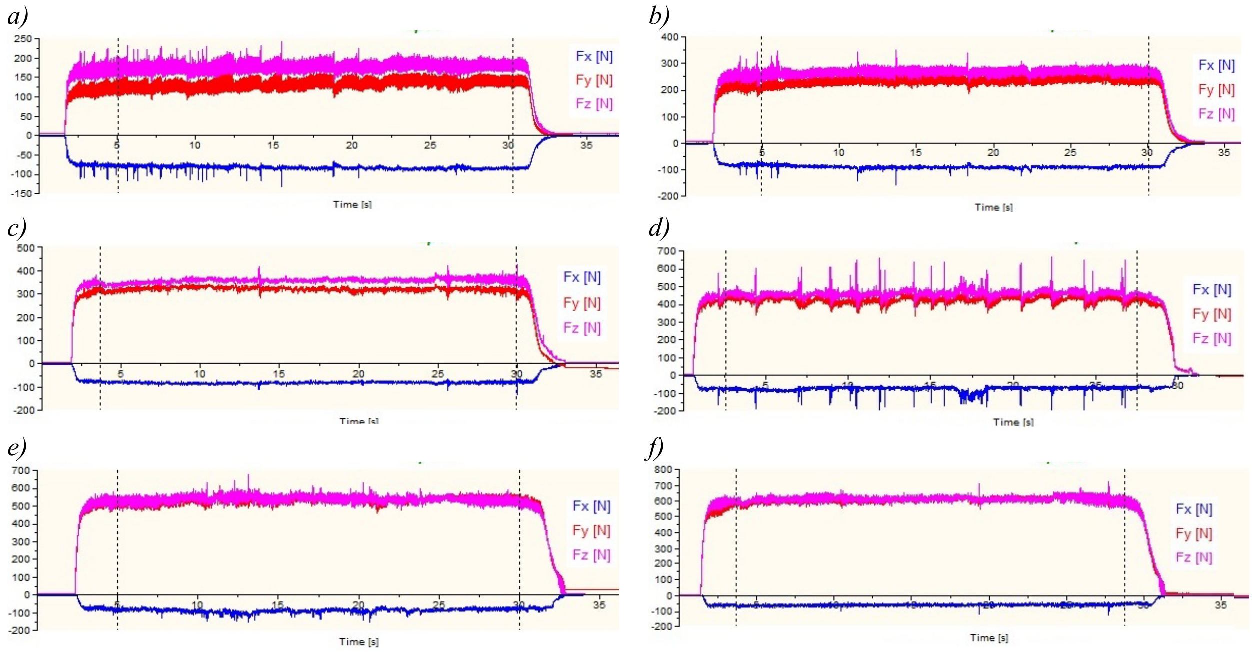

Fig. 4. Turning dynamometer Kistler – cutting forces for depth of cut a) a_p = 0.50 mm, b) a_p = 0.75 mm, c) a_p = 1.00 mm, d) a_p = 1.25 mm, e) a_p = 1.50 mm, f) a_p = 1.75 mm

Table 3 shows the results of statistical analysis for the effect of the depth of cut on the surface roughness parameter Ra. Fig. 5 presents the examples shaft surface profile analysis for depth of cut equal 0.75 and 1.75 mm. Increasing the cutting depth to the value of 0.25 mm, causes increasing the value of the parameter Ra. The lowest value was obtained for Ra equal 1.47 µm for the depth of cut 0.5 mm.

Tab. 3. The results of statistical analysis of surface roughness parameter Ra [μm] for DKM2010 dynamometer

Depth of cut	Mean	Minimum	Maximum	Stand. dev.	Stand. error
0.50	1.47	1.32	1.63	0.10	0.03
0.75	1.51	1.46	1.57	0.04	0.01
1.00	1.57	1.54	1.64	0.03	0.01
1.25	1.55	1.50	1.61	0.04	0.01
1.50	1.63	1.56	1.74	0.06	0.02
1.75	1.67	1.61	1.78	0.06	0.02

a) *b)*

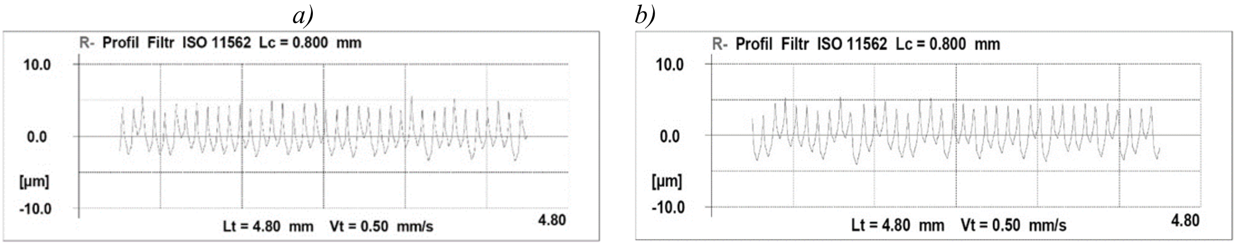

Fig. 5. The examples shaft surface profile analysis for depth of cut a) a_p = 0.75 mm b)) a_p = 1.75 mm

Table 4 shows the results of statistical analysis for the effect of the depth of cut on the surface roughness parameter Ra. The lowest value of this parameter obtained for the cutting depth equal to 0.5 mm. Increasing the value of the constant a_p value of 0.25 mm didn't cause constant increase in the average value Ra. The largest value of Ra = 1.33 μm, and therefore the worst surface roughness obtained for a_p = 0.75 mm. Fig. 6 presents the examples shaft surface profile analysis for depth of cut equal to 0.75 and 1.75 mm.

Tab. 4. Results of statistic analysis of surface roughness parameter Ra [μm] for Kistler dynamometer

Depth of cut	Mean	Minimum	Maximum	Stand. dev.	Stand. error
0.5 mm	0.92	0.89	0.94	0.02	0.01
0.75 mm	1.33	1.23	1.38	0.06	0.02
1.00 mm	1.01	0.94	1.10	0.06	0.02
1.25 mm	1.18	1.15	1.25	0.05	0.02
1.50 mm	1.09	0.97	1.22	0.10	0.03
1.75 mm	1.27	1.12	1.35	0.09	0.03

a) *b)*

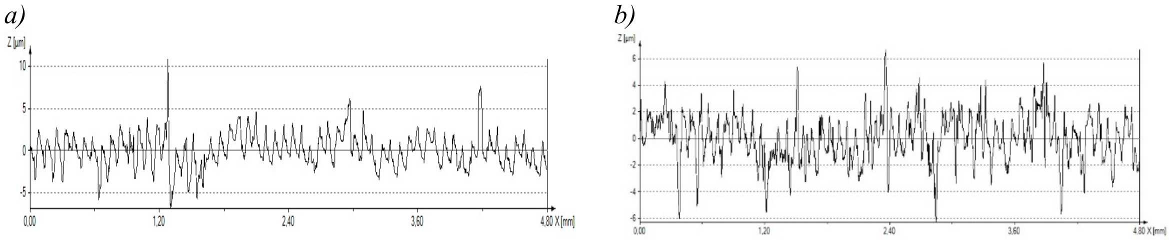

Fig. 6. The examples shaft surface profile analysis for depth of cut a) a_p = 0.75 mm b)) a_p = 1.75 mm

3. Conclusions

Analysis of the results showed significant differences in the values obtained for the cutting forces and the surface roughness parameter Ra. The use of constant cutting parameters, but changing conditions of turning, showed differences between the measurements of cutting forces (F_c i F_z) equal to 193.1 N at the depth of cut a_p = 1.75 mm. But for a_p = 0.5 mm, this difference amounted to 131.3 N. Measurements of the forces of feed show differences not exceeding 10% of the average results obtained for the analysed forces. Whereas, for the radial forces the biggest differences between the values obtained for the depth of cut a_p = 1.75 mm. DKM2010 dynamometer showed significant differences in measurements of forces Fx but in the case of the second dynamometer (Kistler) obtained values of forces Fx were statically insignificant.

The Ra parameter reached an average of 30% less following the process of turning shaft using a Kistler dynamometer relative to the device DKM2010. During turning finishing of shafts, so a big difference in the results obtained measurement of roughness, may result his disqualification.

In preliminary research, the use of speed of cutting equal 150 m / min could have significant influence on the values of parameter of surface roughness and cutting forces. Therefore, during further research will be used in the optimum cutting parameters. In addition will be carried out vibration measurements during the turning using the Brüel & Kjaer analyser.

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