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THE INFLUENCE OF CHANGING OF CUTTING PARAMETERS ON TEMPERATURE AND CUTTING FORCES DURING TURNING PROCESS OF STAINLESS STEEL WITH 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 results of influence of change of cutting parameters on temperature and cutting forces during turning process of stainless steel. A shaft made of 304L stainless steel was used for the research. The cutting process was carried out on a universal CDS 6250 BX-1000 centre lathes. Measurement of cutting forces during lathing process used DKM 2010 turning dynamometer. The turning process was conducted by a cutting tool with CCET09T302R-MF insert by DIJET. During the turning, the following machining parameters were used: cutting speed $V_c = 226$ *m/min, feed* $f = 0.044, 0.062, 0.083, 0.106$ *mm/rev and cutting depth* $a_p = 0.25, 0.5, 0.75, 1.0$ *mm. The chemical composition of steel was measured by Solaris-ccd plus optical spectrometer.*

Keywords: *turning dynamometer, temperature and cutting forces, stainless steel*

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. Seawater pumps belong to a group of centrifugal angular momentum pumps. This kind 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. 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.

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 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 Gdynia Maritime University, deal with issues related to the turning surface of the difficult-to-machine [1, 3-12]. 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 many 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 change of cutting parameters during turning of shafts on the temperature and cutting forces.

2. Research methodology

During the research of temperature and cutting forces the shafts made of stainless steel was used (Fig. 1b). The process of turning was carried out on a universal CDS 6250 BX-1000 lathe centre (Fig. 1a). The lathing process was conducted by a cutting tool with CCET09T302R-MF insert. During the lathing, the following machining parameters were used: cutting speed (V_c), feed (f) and depth of cut (a_p). The value of cutting parameters is presented in Tab. 1.

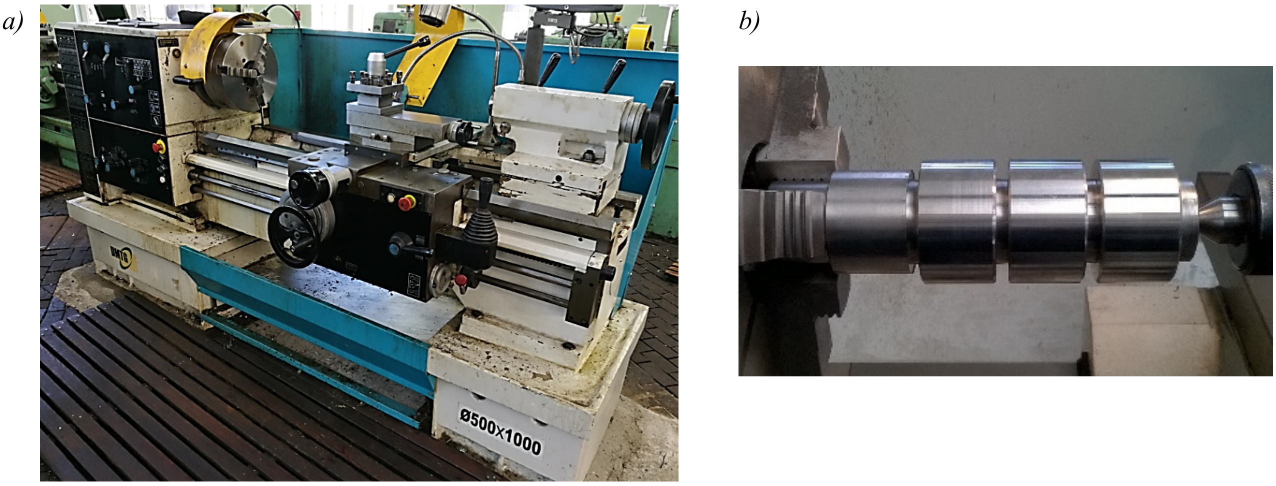

Fig. 1. a) Lathe type: CDS 6250 BX-1000 b) the sample used for turning process

Tab. 1. The cutting parameters used in turning process

Cutting parameters	
V_c [m/min]	226
f [mm/rev]	0.044, 0.062, 0.083, 0.106
a_p [mm]	0.25, 0.5, 0.75, 1.0

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 equipment of DKM 2010 is presented in Fig. 2.

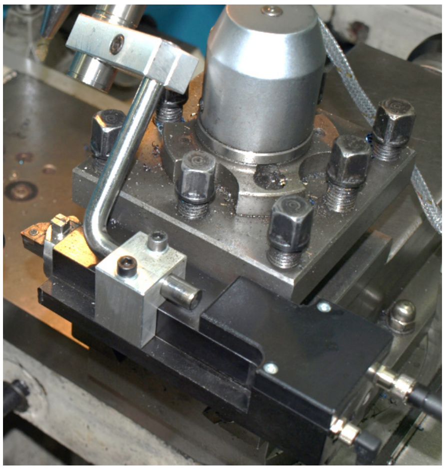

Fig. 2. DKM 2010 turning dynamometer

Analysis of the chemical composition of the sample material was carried out on a Solaris-ccd plus spectrometer (Fig. 3a). It is an optical emission spectrometer with spark excitation by GNR. It performs the analysis of solid samples and metal alloys of different matrices. Percentage contents of selected elements in steel were presented for sample after four-spark test (Fig. 3b).

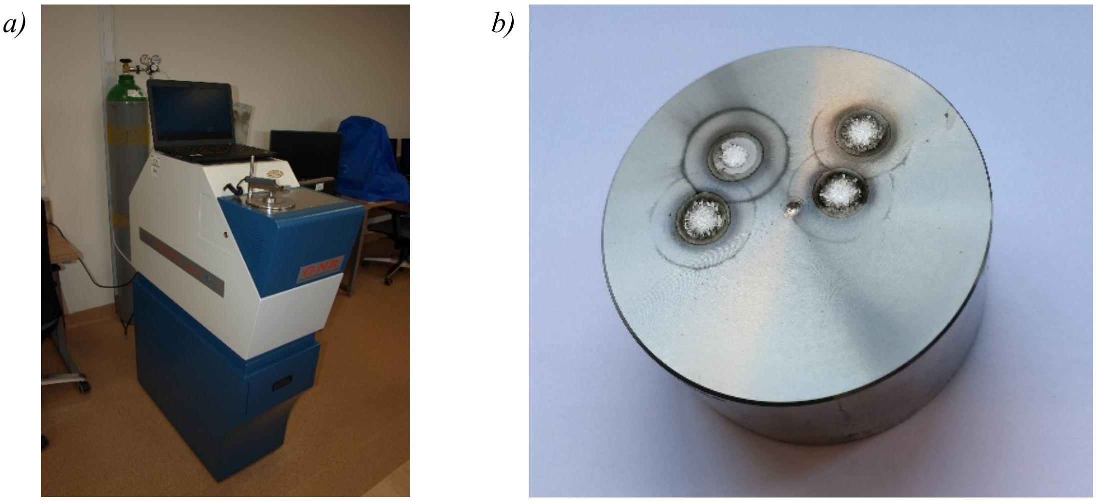

Fig. 3. a) Solaris-ccd plus optical spectrometer b) the sample used for the chemical composition testing

The view of the nose radius of cutting tool before and after the turning process was made on the Smartzoom 5 microscope (Fig. 4).

Fig. 4. Smartzoom 5 microscope

3. Research results

The results of the chemical composition of steel 304L are presents in Tab. 2. Austenitic steels containing 8% Ni have the preferred combination of machinability, mechanical properties and corrosion resistance. They are the most important group of corrosion resistant steels and have a significant share in the production of stainless steels. Machining of stainless steels is classified as group of materials difficult to machining process [2].

Tab. 2. The results of the chemical composition of tested 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	

Table 3 shows the results of the basic statistical analysis of the measurement of F_c force. The highest mean value of force F_c (443 N) was obtained for a cutting depth equal 1 mm and feed 0.106 mm/rev. For each value of the depth of cut, as the feed increases, the value of the F_c force increases too.

Tab. 3. The results of statistic analysis of F_c [N]

No of shaft pins	Cutting parameters		F_c [N]				
	a_p [mm]	f [mm/rev]	Mean	Min	Max	Stand. dev.	Stand. error
1	0.25	0.044	45	39	49	1.51	0.08
2	0.25	0.062	60	55	64	1.51	0.10
3	0.25	0.083	67	62	73	2.08	0.14
4	0.25	0.106	82	78	85	1.28	0.10
5	0.5	0.044	83	74	90	2.47	0.13
6	0.5	0.062	105	98	116	3.82	0.24
7	0.5	0.083	125	116	175	6.46	0.44
8	0.5	0.106	160	147	190	10.04	0.81
9	0.75	0.044	107	101	115	2.48	0.13
10	0.75	0.062	137	127	144	2.78	0.18
11	0.75	0.083	171	164	178	2.97	0.20
12	0.75	0.106	212	203	238	5.58	0.45
13	1	0.044	134	129	138	1.70	0.09
14	1	0.062	410	290	455	30.44	1.92
15	1	0.083	424	374	517	31.73	2.18
16	1	0.106	443	430	459	7.95	0.64

Table 4 presents the basic statistical analysis of the effect of changing the parameters a_p and f on the value of the feed force for cutting depths equal 0.25, 0.5 and 0.75 mm, the feed force did not exceed 20 N. The highest mean values of force F_f were observed for a cutting depth equal

1 mm with value of feed in range 0.062, 0.083 and 0.106 mm/rev. Analysis of the results obtained for the F_p force value (Tab. 5) shows the same relationship. The mean value of the resulting force does not exceed 33 N for depth of cut in range 0.25-0.75 mm. Significant increase of value force was observed for a_p = 1 mm and f = 0.062-0.106 mm/rev.

Tab. 4. The results of statistic analysis of F_f [N]

No of shaft pins	Cutting parameters		F_f [N]				
	a_p [mm]	f [mm/rev]	Mean	Min	Max	Stand. dev.	Stand. error
1	0.25	0.044	2	1	5	0.59	0.03
2	0.25	0.062	3	1	6	0.60	0.04
3	0.25	0.083	4	1	8	0.69	0.09
4	0.25	0.106	5	2	10	0.86	0.11
5	0.5	0.044	16	11	19	1.43	0.07
6	0.5	0.062	16	12	22	2.07	0.13
7	0.5	0.083	16	11	41	2.47	0.17
8	0.5	0.106	19	14	36	4.26	0.34
9	0.75	0.044	20	12	27	2.08	0.11
10	0.75	0.062	19	12	24	2.08	0.13
11	0.75	0.083	21	18	24	1.21	0.08
12	0.75	0.106	20	16	29	1.78	0.14
13	1	0.044	16	13	17	0.66	0.04
14	1	0.062	372	286	421	28.74	1.81
15	1	0.083	340	252	699	86.20	5.92
16	1	0.106	324	307	350	6.43	0.52

Tab. 5. The results of statistic analysis of F_p [N]

No of shaft pins	Cutting parameters		F_p [N]				
	a_p [mm]	f [mm/rev]	Mean	Min	Max	Stand. dev.	Stand. error
1	0.25	0.044	11	8	12	0.63	0.03
2	0.25	0.062	19	17	20	0.60	0.04
3	0.25	0.083	22	21	24	0.67	0.05
4	0.25	0.106	20	11	27	3.98	0.32
5	0.5	0.044	13	11	16	1.21	0.06
6	0.5	0.062	18	16	23	1.38	0.09
7	0.5	0.083	27	22	36	2.00	0.14
8	0.5	0.106	33	25	44	3.96	0.32
9	0.75	0.044	16	10	18	0.90	0.05
10	0.75	0.062	18	10	19	1.10	0.07
11	0.75	0.083	29	26	33	1.05	0.07
12	0.75	0.106	33	24	47	3.16	0.25
13	1	0.044	2	1	3	0.66	0.04
14	1	0.062	226	196	282	14.71	0.93
15	1	0.083	212	195	251	11.80	0.81
16	1	0.106	153	139	169	10.38	0.83

Table 6 presents the results of the basic statistical analysis of temperature measurements during the turning process. The influence changing of depth of cut and feed on the change of temperature on the rake face insert removable cutting tool at a distance of 2 mm from the cutting edge was measurement. The cutting process was carried out dry. For the turning process in the depth of cut range equal 0.25 to 0.75 mm, the mean value of temperatures in the range of 319 to 385°C were obtained. Increasing the depth of cut to 1 mm for value of feed in range 0.062-0.106 mm/rev caused the rise temperature on rake surface above 442°C. The highest value of T = 539°C was obtained for the turning process with a_p = 1 mm and f = 0.062 mm/rev. Large values of standard deviation of temperature measurements indicate interference of the measurement by the temperature rise of the continuous chips. Fig. 5 and 6 show the influence of cutting parameters on the force and cutting temperature.

Tab. 6. The results of statistic analysis of T [N]

No of shaft pins	Cutting parameters		T [°C]				
	a_p [mm]	f [mm/rev]	Mean	Min	Max	Stand. dev.	Stand. error
1	0.25	0.044	339	313	347	5.37	0.29
2	0.25	0.062	344	325	358	5.43	0.29
3	0.25	0.083	337	320	351	6.67	0.36
4	0.25	0.106	319	303	328	5.33	0.29
5	0.5	0.044	336	325	345	3.03	0.16
6	0.5	0.062	342	319	362	11.36	0.62
7	0.5	0.083	364	322	470	24.53	1.33
8	0.5	0.106	339	313	347	5.40	0.29
9	0.75	0.044	334	328	340	2.89	0.16
10	0.75	0.062	348	325	368	9.29	0.50
11	0.75	0.083	365	329	399	10.17	0.55
12	0.75	0.106	385	362	454	12.50	0.68
13	1	0.044	336	329	341	1.96	0.11
14	1	0.062	539	411	625	43.70	2.37
15	1	0.083	488	431	584	27.51	1.49
16	1	0.106	442	401	469	11.93	0.65

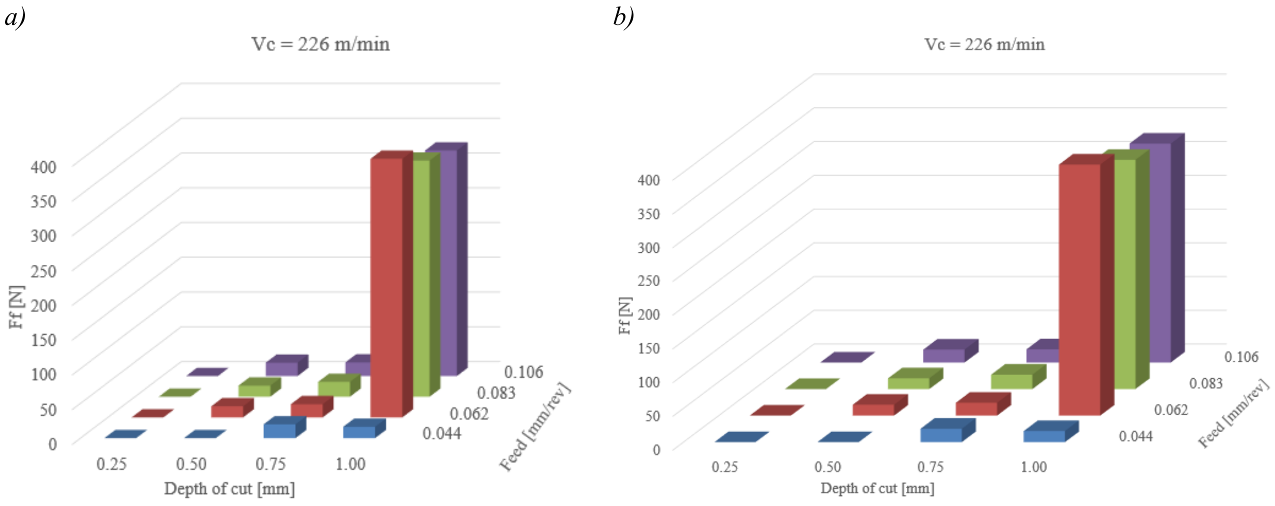

Fig. 5. The influence of changing of cutting parameters on force values a) F_c, b) F_f

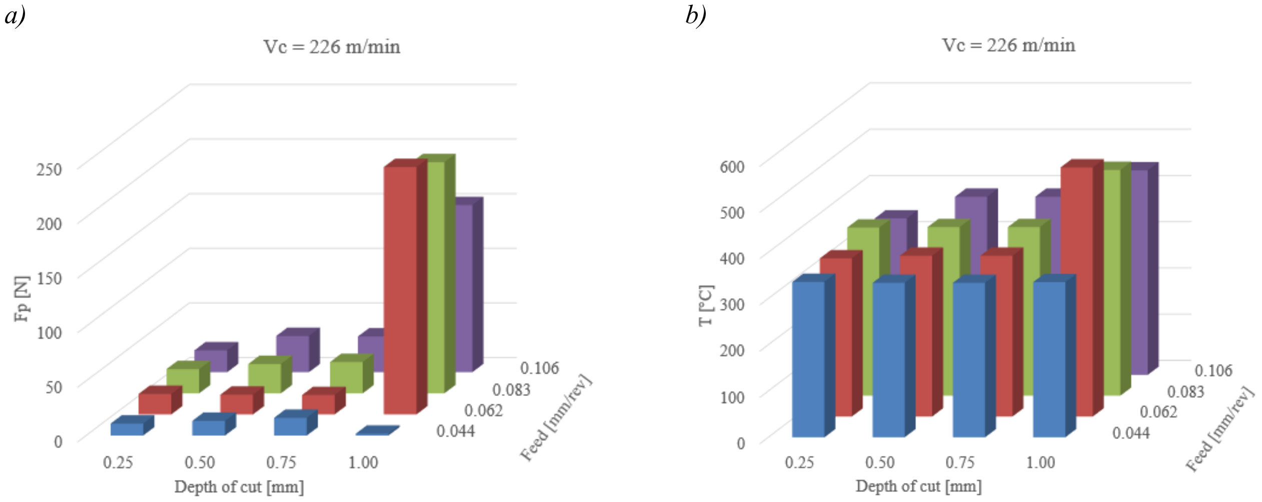

Fig. 6. The influence of changing of cutting parameters on value: a) F_p, b) T

During the research, significant increase in the analysed forces and cutting temperature was observed for the turning process with a depth of cut equal 1 mm and feed in the range of 0.062 to 0.106 mm/rev. Fig. 7 shows a view of the new cutting insert and after the turning process. The nose radius has been damaged on the flank surfaces are clearly visible wear surface defects. Such damage of the nose of the insert radius could have impact on the significant changes in the analysed forces as well as on the temperatures during the cutting process. During the test, wear of the nose radius of the cutting insert was not observed.

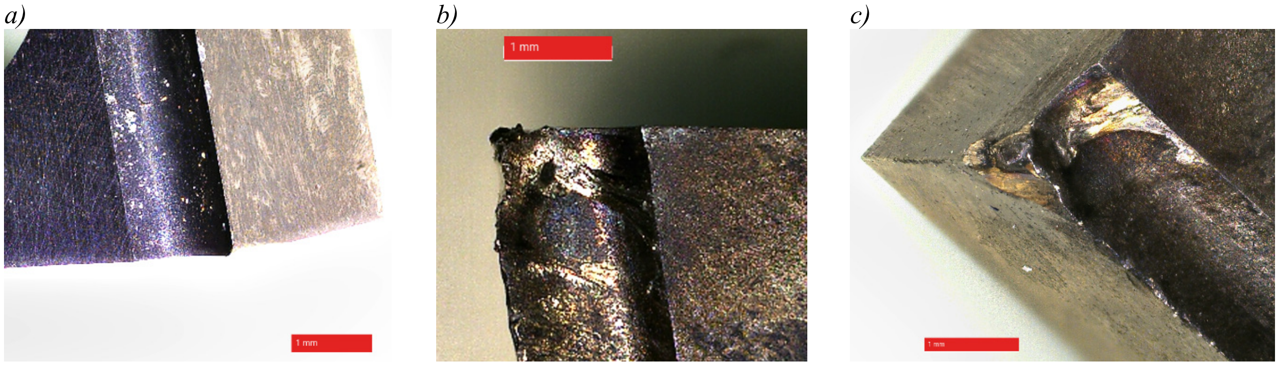

Fig. 7. View of insert: a) before, b) after turning process

4. Conclusions

This article is one of a series on determining the set of input, constant, and disturbing factors for the turning process of shaft pins made of a stainless steel. Analysis of the results showed significant differences in the values obtained for the cutting forces and temperature during changing of cutting parameters. The turning process was carried out CCET09T302R-MF insert with the depth of cut a_p = 0.25, 0.5, 075 mm and feed 0.044 to 0.106, made it possible to obtain favourable machining conditions. The individual forces do not exceed the mean values for F_c = 212 N, F_f = 20 N, F_p = 33 N. Increasing the depth of cut to 1 mm resulted in a very significant increase in these forces. This could be due to damage to the insert of cutting tool. Therefore, it is necessary to repeat the research for a higher range of cutting depth.

In the next research, a multiple regression analysis will be performed to determine the equations for individual forces for variable treatment conditions. In addition, research is conducted to determine the effect of changing treatment conditions on the surface roughness parameters. The tests will be done on the T8000 profilometer.

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