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THE INFLUENCE OF CHANGING OF CUTTING PARAMETERS ON TEMPERATURE AND CUTTING FORCES DURING TURNING PROCESS BY 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 turning process used DKM 2010 turning dynamometer. A cutting tool conducted the turning process 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 *= 0.375; 0.625; 0.875 mm. The chemical composition of steel was measured by Solaris-ccd plus optical spectrometer. The Smartzoom 5 microscope made the view of the nose radius of cutting tool.*

Keywords: *turning dynamometer, temperature and cutting forces, cutting parameters, 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 of pumps is 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 spline ways 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, 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, 2, 4-13]. 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 is a continuation of the research on influence of changing the treatment condition during turning process of stainless steel by *CCET09T302R-MF insert.* The publish presents the results of influence of change of cutting parameters during turning of shafts on the temperature and cutting forces.

2. Research methodology

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

a) *b)*

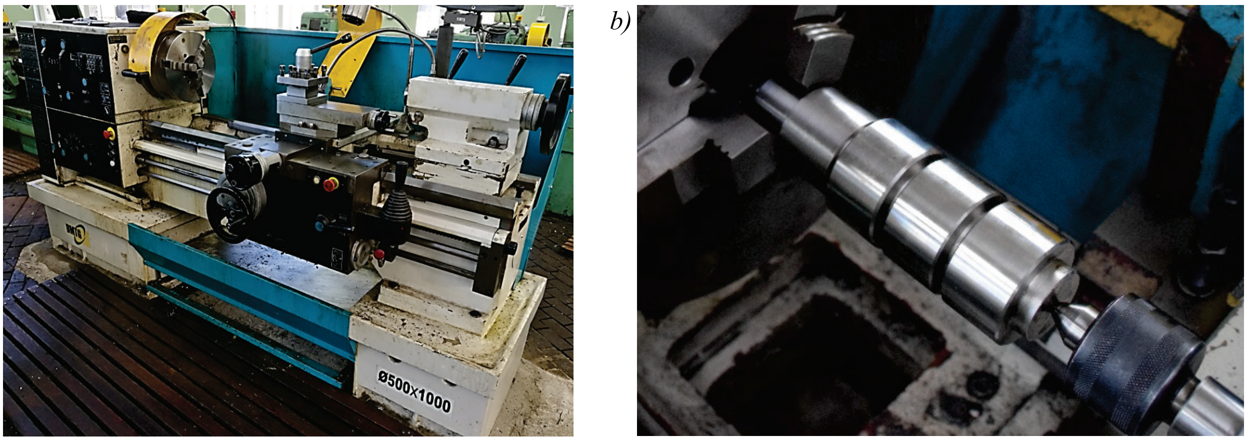

Fig. 1. Lathe type: CDS 6250 BX-1000 (a) and the sample used for turning process (b)

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]	0.375; 0.625; 0.875

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 ϰr into 45, 60, 70, 90°. The equipment of DKM 2010 is presented in Fig. 2.

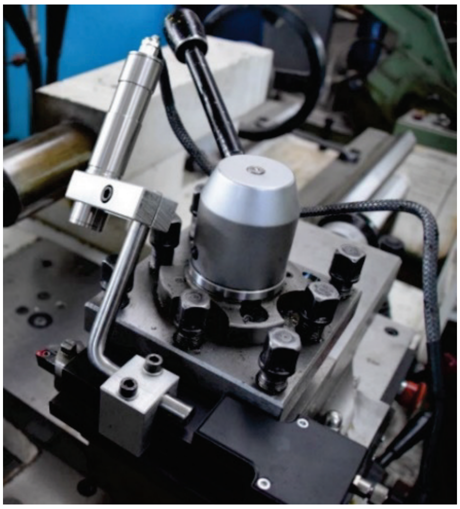

Fig. 2. DKM 2010 turning dynamometer

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 six-spark test (Fig. 3b). The first two attempts were made as preliminary and they were not included in the test results.

a)

b)

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

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

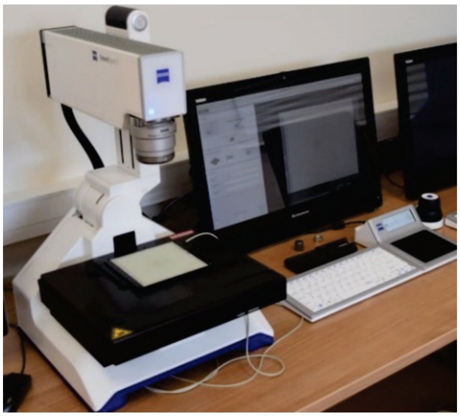

Fig. 4. Smartzoom 5 microscope

3. Research results

The results of the chemical composition of 304L steel is presented 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 [3].

Tab. 2. The results of the chemical composition of tested steel [%]

	C	Si	Mn	P	S	Cr	Mo	Ni	Nb
mean	0.021	0.433	1.414	0.021	0.028	16.246	0.490	7.735	0.007
max	0.026	0.439	1.438	0.022	0.028	18.006	0.491	7.809	0.008
min	0.019	0.429	1.392	0.020	0.027	11.126	0.488	7.665	0.006
	Al	Cu	Co	B	Ti	V	W	Fe	
mean	0.004	0.496	0.125	0.002	0.027	0.060	0.024	71.119	
max	0.004	0.501	0.126	0.002	0.029	0.066	0.025	71.177	
min	0.003	0.487	0.122	0.002	0.025	0.056	0.023	71.035	

Table 3 shows the results of the basic statistical analysis of the measurement of Fc force. The highest mean value of Fc force (324 N) was obtained for a cutting depth equal 0.875 mm and feed 0.106 mm/ rev. For each value of the depth of cut, as the feed increases, the value of the Fc force increases too.

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

No. of shaft pin	Cutting parameters		F_c [N]				
	a_p [mm]	f [mm/rev]	Mean	Min	Max	Stand. dev.	Stand. error
1	0.375	0.044	64	59	68	1.46	0.08
2	0.375	0.062	83	76	98	2.87	0.18
3	0.375	0.083	100	93	109	2.88	0.21
4	0.375	0.106	126	115	159	7.82	0.63
5	0.625	0.044	97	78	107	2.85	0.14
6	0.625	0.062	124	119	132	2.62	0.16
7	0.625	0.083	151	143	169	3.95	0.30
8	0.625	0.106	224	182	287	23.82	1.92
9	0.875	0.044	171	146	234	22.00	1.15
10	0.875	0.062	210	182	291	18.56	1.12
11	0.875	0.083	292	232	346	26.31	1.82
12	0.875	0.106	324	297	407	19.61	1.41

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 all cutting depths, the mean of feed force did not exceed 100 N. The highest mean values of force F_f were observed for a depth of cut equal 0.875 mm with value of feed in range 0.083 and 0.106 mm/rev.

Table 5 presents the basic statistical analysis of the effect of changing the parameters a_p and f on the value of the F_p force. Analysis of the results obtained for the F_p force value shows the same relationship. The mean value of the resulting force does not exceed 110 N for depth of cut in range 0.375-0.625 mm. Significant increase of force was observed for $a_p = 0.875$ mm, $f = 0.083$ and 0.106 mm/rev.

Tab. 4. The results of statistical analysis of Ff [N]

No. of shaft pin	Cutting parameters		F_f [N]				
	a_p [mm]	f [mm/rev]	Mean	Min	Max	Stand. dev.	Stand. error
1	0.375	0.044	7	1	12	5.11	0.28
2	0.375	0.062	14	11	18	2.69	0.17
3	0.375	0.083	15	11	19	3.67	0.26
4	0.375	0.106	12	4	27	4.03	0.32
5	0.625	0.044	17	11	25	2.10	0.11
6	0.625	0.062	19	13	24	1.98	0.12
7	0.625	0.083	23	14	36	2.65	0.20
8	0.625	0.106	81	12	237	51.23	4.13
9	0.875	0.044	61	47	118	11.99	0.62
10	0.875	0.062	43	13	90	17.60	0.98
11	0.875	0.083	90	44	130	17.49	1.21
12	0.875	0.106	86	72	111	7.57	0.54

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

No. of shaft pin	Cutting parameters		F_p [N]				
	a_p [mm]	f [mm/rev]	Mean	Min	Max	Stand. dev.	Stand. error
1	0.375	0.044	22	19	24	0.57	0.03
2	0.375	0.062	29	26	32	0.84	0.05
3	0.375	0.083	36	33	40	1.34	0.10
4	0.375	0.106	44	4	27	4.03	0.32
5	0.625	0.044	25	19	28	1.52	0.08
6	0.625	0.062	32	29	34	1.32	0.08
7	0.625	0.083	33	25	47	2.84	0.22
8	0.625	0.106	107	23	212	61.76	4.98
9	0.875	0.044	99	73	197	30.57	1.59
10	0.875	0.062	74	27	135	21.90	1.22
11	0.875	0.083	160	56	196	20.22	1.40
12	0.875	0.106	181	147	204	8.66	0.62

Table 6 presents the results of the basic statistical analysis of temperature measurements during the turning process. The influence of changing the 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 0.375 to 0.875 mm, the mean value of temperatures in the range of 385 to 578°C were obtained. Increasing the depth of cut to 0.875 mm for feed in range 0.083-0.106 mm/rev caused the rise temperature on rake surface above 500°C. The highest mean values of $T = 578$°C and $T = 557$°C was obtained for the turning process with $a_p = 0.625$ mm, $f = 0.106$ mm/rev and $a_p = 0.875$ mm, $f = 0.083$ 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 shows the influence of changing of cutting parameters on the forces and cutting temperature.

Figure 7 shows a view of the new cutting insert and after the turning process. The nose radius has been damaged on the flank surfaces. A significant defect of the plate was noted on the cutting edge. 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. During the research significant increase in the analysed forces and cutting temperature was observed for the turning process with a depth of cut equal 0.875 mm and feed in the range of 0.062 to 0.106 mm/rev. Significant increase of values of measured forces F_p, F_f and cutting temperature occurred during the cutting process with a depth of cut equal 0.625 mm and feed 0.106 mm/rev. The reason for the increase could be the rapid wear of the cutting edge and the surface of the cutting tool.

Tab. 6. The results of statistical analysis of T [°C]

No. of shaft pin	Cutting parameters		T [°C]				
	a_p [mm]	f [mm/rev]	Mean	Min	Max	Stand. dev.	Stand. error
1	0.375	0.044	393	363	406	3.99	0.22
2	0.375	0.062	413	368	445	11.95	0.74
3	0.375	0.083	432	377	466	17.18	1.23
4	0.375	0.106	445	388	510	18.54	1.49
5	0.625	0.044	385	363	406	6.28	0.32
6	0.625	0.062	405	352	455	21.52	1.33
7	0.625	0.083	475	415	521	17.01	1.31
8	0.625	0.106	578	428	742	62.72	5.05
9	0.875	0.044	420	363	488	29.19	1.52
10	0.875	0.062	386	308	454	25.84	1.44
11	0.875	0.083	557	373	798	99.03	5.92
12	0.875	0.106	503	395	740	56.32	4.03

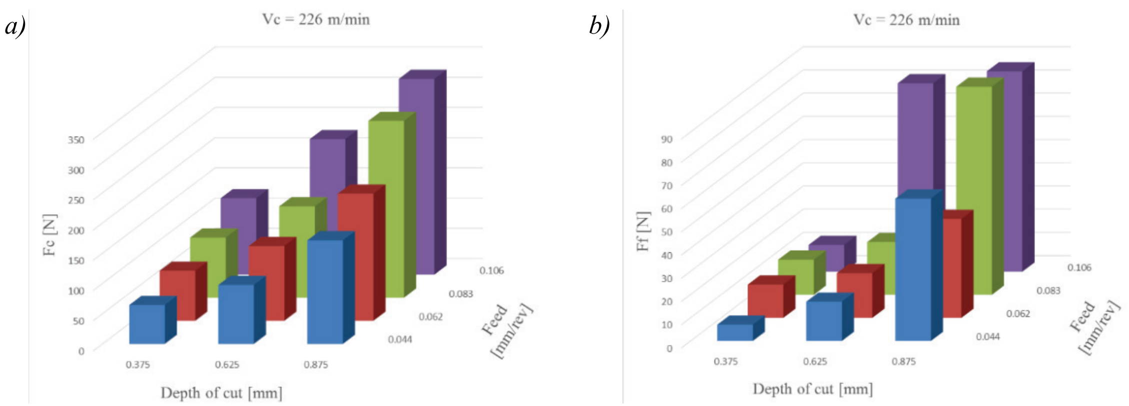

Fig. 5. The influence of changing of cutting parameters on force values: F_c (a), F_f (b)

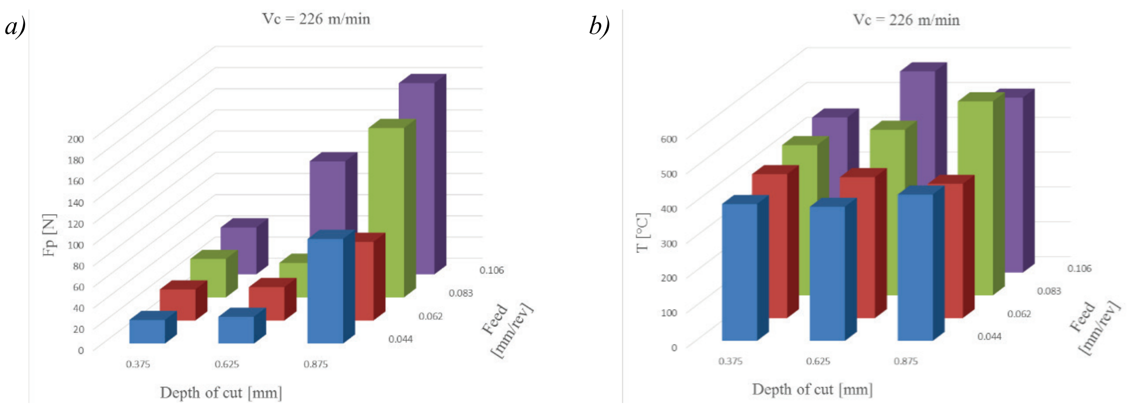

Fig. 6. The influence of changing of cutting parameters on value: F_p (a), T (b)

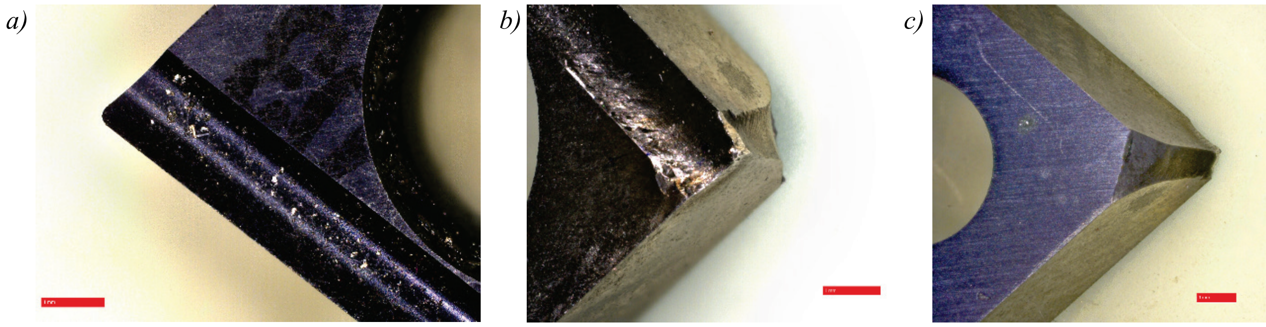

Fig. 7. View of insert: a) before; b) after turning process (view of the face surface); c) after turning process (view of basic of insert)

4. Conclusions

Modern processes of waste treatment, especially difficult-to-work materials, which are very widely used in industry, should ensure the best possible quality of products, high efficiency, economy, reliability and eco-efficiency. Due to the high requirements of elements made of difficult materials and the need for effective simultaneous machining of these materials are carried out extensive research on the improvement of machining processes.

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 by CCET09T302R-MF insert with the depth of cut a_p = 0.375, 0.625 and 0.875 mm and feed 0.044 to 0.106, made it possible to obtain favourable machining conditions.

Increasing the depth of cut and feed resulted in a regular increase in F_c force. Increasing the depth of cut to 1 mm caused a very significant increase in F_p and F_f forces. This may be due to damage to the cutting tool insert. Therefore, it is necessary to repeat the tests to verify the wear of the cutting insert for the cutting depth above 0.75 mm.

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.

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