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THE ANALYSIS OF CUTTING TOOL GEOMETRIC ON CUTTING FORCES AND SURFACE ROUGHNESS OF STEEL APPLIED TO MARINE PUMPS SHAFT PINS

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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 finishing lathing on the cutting forces and surface roughness of stainless steel. The research was performed on a roller 60 mm in diameter made of X5CrNi18-10 steel. The finish tooling of pump shaft pins was carry 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. During the research, the effect of cutting tool geometric on cutting forces and surface roughness of steel applied to marine pumps shaft pins ware tested. In addition, the influence of cutting tool geometric on cutting temperatures was determined.

Keywords: *turning dynamometer, cutting forces, cutting temperature, surface roughness, 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 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.

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 [8]. 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 [9]. 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 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.

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 sulfide, whose positive influence on machinability is confirmed by the type of chips (short and brittle), smoother surfaces of workpieces and less tool wear.

The group of steels with improved machinability are marked X5CrNi18-10. This steel is characterized by high resistance to intergranular corrosion (extremely low carbon content) and has been used: in engineering and nuclear, construction and architecture, transport devices, in contact with food, pharmaceutical and cosmetic industries, in the construction of chemical apparatus and vehicles, in the manufacture of surgical instruments, sanitation items and household goods and artistic products.

Article presents the research of influence of cutting tool geometry on the cutting forces, temperature and surface roughness to the process of lathing X5CrNi18-10 stainless steel. Many scientific centres, including the Gdynia Maritime University, deal with issues related to the turning surface of the difficult-to-machine [3-7].

1. Research methodology

The process of finish machining of shaft pins ϕ 60 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 were conducted by a cutting tool with removable inserts. During the lathing the following machining parameters were used: cutting speed V_c = 160 m/min, feed f = 0.106 mm/rev, cutting depth a_p = 0.5 mm. The shafts which were used in research are presented in Fig. 1.

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. The temperature measurement is based on radiation principle on a spot not greater than 2 mm. 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 presented in Fig. 2. The surface roughness was measured by T8000 profilometer.

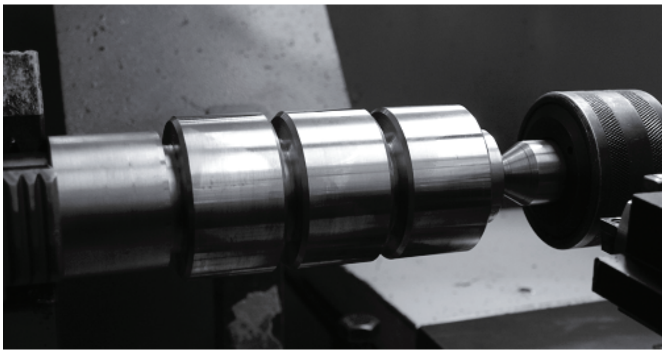


Fig. 1. Sample used in the resarch

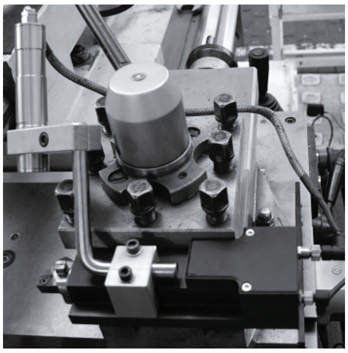


Fig. 2. Turning dynamometer DKM 2010

2. Research results

In the research of lathing process used standard inserts (MF), inserts with increased tolerance (UM) and inserts with Wiper technology. Any type of inserts was also analysed due to the nose radius $r_ε$ = 02, 04, 08 mm. The cutting process was performed at side angle of 90°. The cutting process was carried out dry. Tab. 1 shows the results of statistical analysis values obtained for the cutting force (F_c), feed force (F_f) and radial force (F_p).

Tab. 1. The results of statistical analysis of cutting forces – F_c, feed forces F_f and radial forces F_p

Inserts code	CCMT 09T302 MF	CCMT 09T304 MF	CCMT 09T308 MF	CCGT 09T302 UM	CCGT 09T304 UM	CCGT 09T308 UM	CCMT 09T302 WF	CCMT 09T304 WF	CCMT 09T308 WF
F_c [N]									
Mean	195	180	164	159	171	138	177	172	197
Minimum	184	168	146	144	155	122	149	157	176
maximum	209	196	181	175	185	156	195	191	207
Stand. Dev.	4.7	5.7	7.0	5.9	5.0	8.6	7.1	6.0	3.6
Stand.Error	0.19	0.23	0.28	0.24	0.20	0.35	0.28	0.24	0.14
F_f [N]									
Mean	86	70	54	44	34	21	57	60	57
Minimum	75	63	47	39	29	17	51	53	52
maximum	94	74	61	48	40	25	65	65	61
Stand. Dev.	5.7	2.4	3.4	2.0	2.4	1.4	2.3	2.4	1.7
Stand.Error	0.23	0.10	0.14	0.08	0.10	0.06	0.09	0.10	0.07
F_p [N]									
Mean	81	108	143	38	44	56	55	89	114
Minimum	75	102	137	34	38	49	50	84	110
maximum	86	114	148	43	50	58	59	93	120
Stand. Dev.	2.1	3.5	2.3	2.2	3.1	0.9	1.4	2.0	2.5
Stand.Error	0.09	0.14	0.09	0.09	0.12	0.04	0.05	0.08	0.10

The highest average value of the cutting force F_c = 197 N obtained for inserts with Wiper technology (r_ε 08) and for the standard insert with nose radius r_ε 02, wherein the average value of F_c = 195 N. The lowest average value of F_c = 138 N were obtained for insert UM for r_ε 08. Analysis of feed force showed that the MF and UM inserts of this force decreases with increasing nose radius. For inserts with Wiper technology value remain at the same level. Of the tested plates lowest value of the force F_f registered for the insert CCGT 09T308 UM (F_f = 21 N), whereas the highest value obtained during the lathing of insert CCMT 09T302 MF (F_f = 86 N). The average value of radial force for all groups of inserts increases with increase of the value of the nose radius. The highest force F_p = 143 N were obtained for the insert CCMT 09T308 MF, while the lowest F_p = 38 N for the insert UM CCGT 09T302. Fig. 3 shows the exemplary measurement of cutting force (F_c), feed force (F_f) and radial force (F_p) for lathing process used inserts CCMT 09T308 WF.

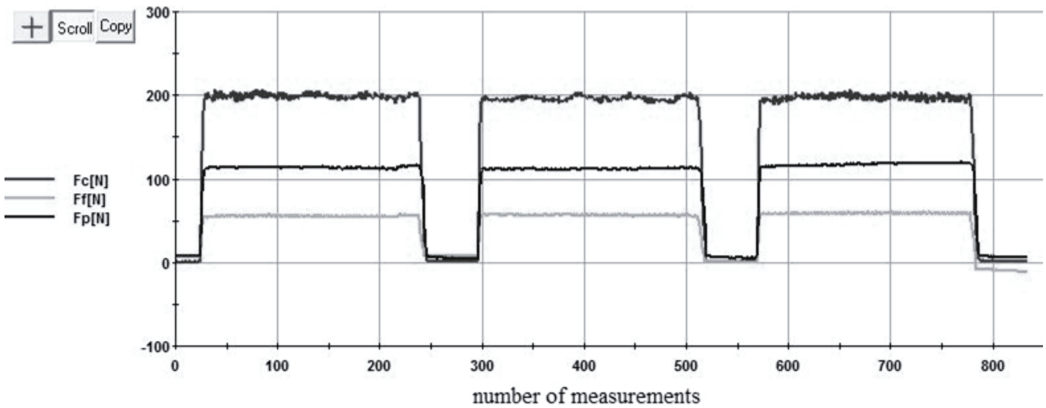


Fig. 3. Exemplary measurement of F_c, F_f and F_p for lathing process with CCMT 09T308 WF insert

Table 2 shows the results of measurement of the statistical analysis for cutting temperature. The highest average value of the cutting temperature (T = 422°C) obtained on the rake face during the lathing process with CCMT 09T308 WF insert. The lowest average value of T = 333°C were obtained for the CCGT 09T304 UM insert. Analysis of the results showed that for each type of inserts, highest values of cutting temperature were obtained for nose radius r_ε 08. Example measurement of cutting temperature for carried out of lathing process is shown in Fig. 4.

Tab. 2. The results of statistical analysis of cutting temperatures

Inserts code	CCMT 09T302 MF	CCMT 09T304 MF	CCMT 09T308 MF	CCGT 09T302 UM	CCGT 09T304 UM	CCGT 09T308 UM	CCMT 09T302 WF	CCMT 09T304 WF	CCMT 09T308 WF
T [°C]									
Mean	338	334	381	346	333	366	366	399	422
Minimum	325	320	372	337	322	343	340	386	403
maximum	349	347	397	351	341	388	386	414	436
Stand. Dev.	3.5	6.0	4.3	1.8	2.7	8.2	8.7	4.2	6.0
Stand.Error	0.14	0.25	0.17	0.07	0.11	0.32	0.35	0.17	0.24

During the lathing process of stainless steel important role plays a geometry of the cutting tool, resulting in the formation of the correct chip. Temperature measurement is disturbed, in the moment, when on the rake face is produce of continuous chip.

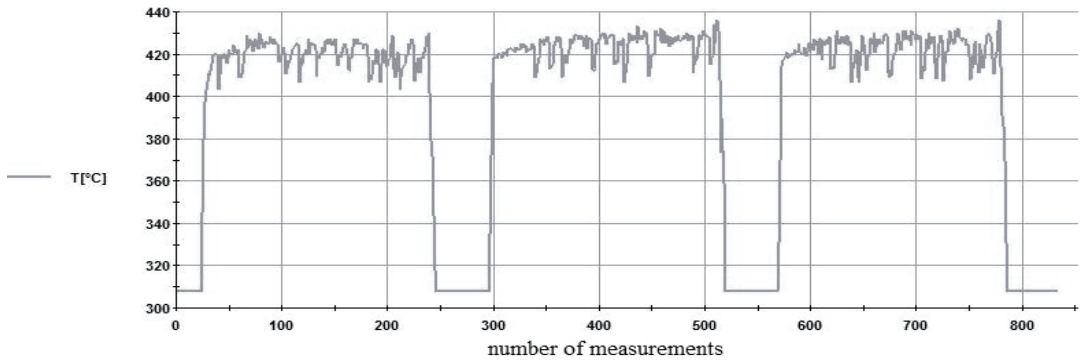


Fig. 4. Exemplary measurement of cutting temperature for lathing process with CCMT 09T308 WF insert

Example graph of temperature measurement, where the continuous chip was made is present in Fig. 5. At the first shaft pin, at the start of the cutting process, and the third shaft pin can be observed distortion of measuring temperature of the continuous chip.

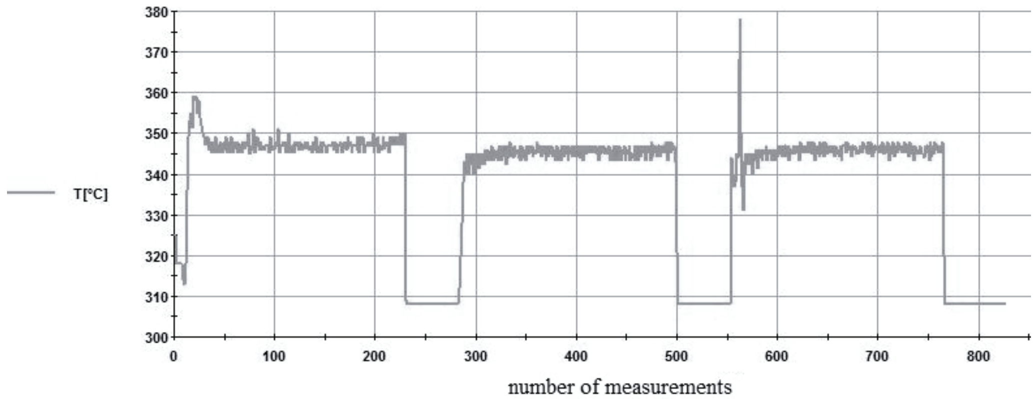


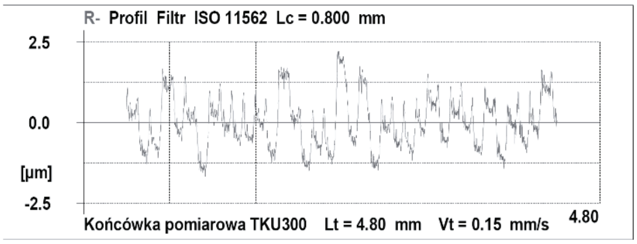
Fig. 5. Exemplary measurement of cutting temperature

Table 3 shows the results of statistical analysis for the effect of the depth of cut on the surface roughness parameter R_a.

Tab. 3. The results of statistical analysis of surface roughness parameter R_a [μm]

Inserts Code	Mean	Minimum	Maximum	Stand. dev.	Stand. error
CCMT 09T302 MF	1.16	1.06	1.30	0.08	0.03
CCMT 09T304 MF	1.01	0.96	1.07	0.03	0.01
CCMT 09T308 MF	0.69	0.57	0.82	0.08	0.03
CCGT 09T302 UM	2.02	1.90	2.17	0.10	0.03
CCGT 09T304 UM	1.34	1.24	1.39	0.05	0.02
CCGT 09T308 UM	1.01	0.96	1.06	0.03	0.01
CCMT 09T302 WF	0.81	0.72	0.95	0.08	0.03
CCMT 09T304 WF	0.65	0.54	0.76	0.08	0.03
CCMT 09T308 WF	0.72	0.66	0.77	0.05	0.02

Analysis of the results showed that the inserts with Wiper technology, reached the lowest values for surface roughness parameter R_a in the midst of all the tested inserts. For inserts MF and UM types, parameter value R_a decreases with increasing the nose radius. The obtained value of the parameter R_a for nose radius 02 is nearly twice as large as the nose radius 08. The lowest average value of the parameter R_a = 0.65 μm at the midst of test inserts were obtained for inserts WF with r_ε 04. The highest mean value of the parameter R_a = 2.02 μm were obtained for CCGT 09T302 UM insert. Fig. 6 shows an exemplary shaft surface profile after lathing process.



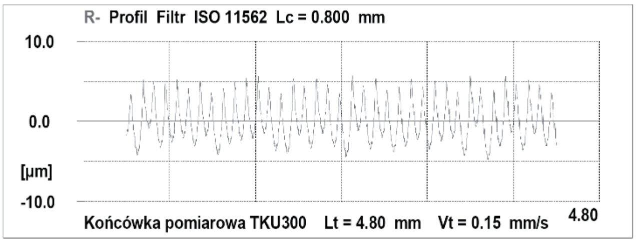


Fig. 6. The examples shaft surface profile analysis for inserts a) CCMT 09T304 WF b) CCGT 09T302 UM

3. Conclusions

During the research of lathing process used inserts for finishing of stainless steel, a mean value for the cutting forces between 138 - 197 N, feed force 21 - 86 N and the radial forces 38 - 143 N. The lowest mean values of cutting force and feed force during the lathing obtained for insert CCGT 09T308 UM. The lowest mean values of radial force was observed for insert CCGT 09T302 UM. Radial forces increases with increasing the nose radius for all types of inserts. The used of turning inserts with Wiper technology allowed to obtain surface properties to the lowest values of the parameter R_a for all analysed nose radius.

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