THE INFLUENCE OF TREATMENTS CONDITIONS ON CUTTING FORCES AND TEMPERATURE DURING FINISH TURNING OF STAINLESS STEEL 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 research results referring to the analysis of the influence of cutting parameters on surface roughness parameter of marine pump shaft. The turning process was carried out on a universal CDS6250BX-1000 centre lathe. The research was performed on a shaft made of X5CrNi18-10 (AISI 304L) stainless steel. During lathing process used DKM 2010 turning dynamometer. The finishing turning process was carried out by cutting tool with CCET09T302R-MF removable insert by DIJET. During turning the following machining parameters were used: cutting speed *Vc* = 226 m/min, feed *f* = 0.044; 0.062; 0.083; 0.106 mm/rev and cutting depth *ap* = 0.25; 0.375; 0.5; 0.625; 0.75; 0.875; 1.0 mm. The goal of the paper was to define the influence of treatment conditions on cutting forces and temperature. Chemical composition of steel was measured by Solaris-ccd plus optical spectrometer.

Keywords: Finish turning, cutting forces, cutting temperature, stainless steel, marine pump shaft

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. 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 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 fulfill its tasks under certain conditions and time [1]. 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 [2]. 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 [3,4]. The most common and universal way to remove layers of abraded material is the cutting process.

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 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.

Many scientific centers, including the Gdynia Maritime University, deal with issues related to the turning surface of the difficult-to-machine [5-13]. 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 a lot of 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.

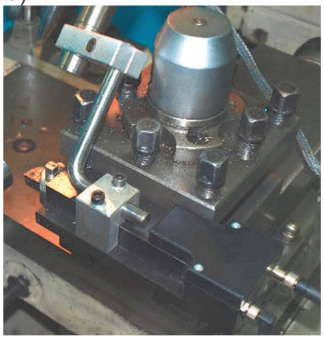
The article presents the results of influence of changing cutting parameters during turning of shafts made of stainless steel on the cutting forces and temperature.

2. RESEARCH METHODOLOGY

The research was performed on a shaft made of X5CrNi18-10 (AISI 304L) stainless steel (**Figure 1c**). The process of turning was carried out on a lathe CDS6250BX-1000 type (**Figure 1a**) by a cutting tool with removable insert CCET09T302R-MF type by DIJET. The cutting parameters used in the finish lathing process are presented in **Table 1**: cutting speed, feed and depth of cut. During cutting process DKM2010 turning dynamometer was used. 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 temperature 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 dynamometer is presented in **Figure 1b**.

a)

b)



c)

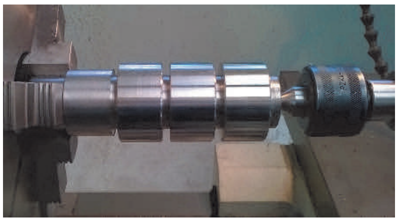


Figure 1 a) CDS 6250 BX-1000 lathe b) turning dynamometer c) sample used in the research

Table 1 Technological parameters for the cutting process

<table>
<tr><th colspan="28">Cutting speed Vc = 226 m/min</th></tr>
<tr><th colspan="28">Depth of cut (mm)</th></tr>
<tr><td colspan="4">0.25</td><td colspan="4">0.375</td><td colspan="4">0.5</td><td colspan="4">0.625</td><td colspan="4">0.75</td><td colspan="4">0.875</td><td colspan="4">1.0</td></tr>
<tr><th colspan="28">Feed (mm/rev)</th></tr>
<tr><td colspan="7">0.044</td><td colspan="7">0.062</td><td colspan="7">0.083</td><td colspan="7">0.106</td></tr>
</table>

Analysis of the chemical composition of the sample material was carried out on a Solaris-ccd plus spectrometer (**Figure 2a**). 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 was presented for sample after four spark test (**Figure 2 b**). The view of the shaft surface after the turning process was observed by the Smartzoom 5 microscope (**Figure 2 c**).

a) b) c)

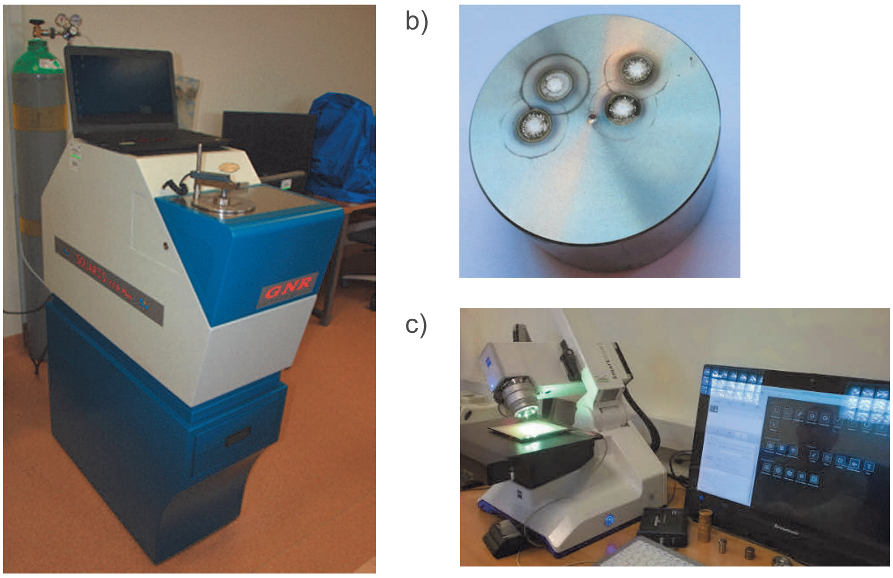


Figure 2 a) Solaris-ccd plus optical spectrometer b) the sample used for testing the chemical composition of the steel c) Smartzoom 5 microscope

3. RESEARCH RESULTS

The results of the chemical composition of steel X5CrNi18-10 are presents in **Table 2**.

Table 2 The results of the chemical composition of steel [%]

<table>
<tr><th></th><th>C</th><th>Si</th><th>Mn</th><th>P</th><th>S</th><th>Cr</th><th>Mo</th><th>Ni</th><th>Nb</th></tr>
<tr><td>mean</td><td>0.037</td><td>0.457</td><td>1.638</td><td>0.028</td><td>0.030</td><td>18.261</td><td>0.473</td><td>7.760</td><td>0.008</td></tr>
<tr><td>max</td><td>0.057</td><td>0.478</td><td>1.659</td><td>0.030</td><td>0.033</td><td>18.332</td><td>0.482</td><td>7.847</td><td>0.010</td></tr>
<tr><td>min</td><td>0.025</td><td>0.440</td><td>1.612</td><td>0.026</td><td>0.028</td><td>18.164</td><td>0.465</td><td>7.628</td><td>0.006</td></tr>
<tr><th></th><th>Al</th><th>Cu</th><th>Co</th><th>B</th><th>Ti</th><th>V</th><th>W</th><th colspan="2">Fe</th></tr>
<tr><td>mean</td><td>0.003</td><td>0.483</td><td>0.125</td><td>0.002</td><td>0.026</td><td>0.057</td><td>0.021</td><td colspan="2">70.594</td></tr>
<tr><td>max</td><td>0.004</td><td>0.490</td><td>0.127</td><td>0.002</td><td>0.027</td><td>0.058</td><td>0.021</td><td colspan="2">70.731</td></tr>
<tr><td>min</td><td>0.002</td><td>0.471</td><td>0.124</td><td>0.001</td><td>0.023</td><td>0.057</td><td>0.020</td><td colspan="2">70.482</td></tr>
</table>

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 [14].

Figure 3 shows the results the influence of cutting parameters on the measurement of *Fc* force. The highest mean value of force *Fc* (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 *Fc* force increases too.

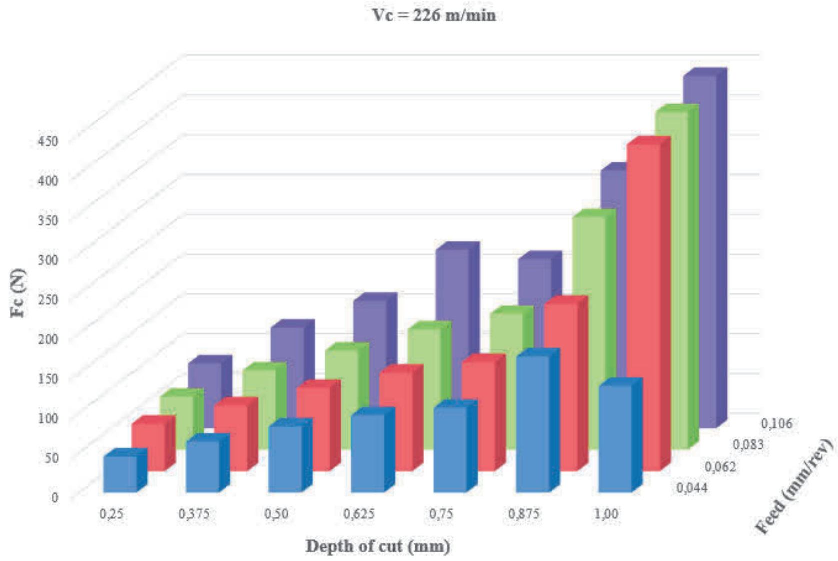


Figure 3 The influence of cutting parameters on *Fc* (N)

Figure 4 presents the analysis of the effect of changing the parameters *ap* and *f* on the value of the feed force. For cutting depths in range 0.25 to 0.875 mm, the mean value of feed force did not exceed 100 N. The highest mean values of force *Ff* were observed for a cutting depth equal 1 mm with value of feed in range 0.062, 0.083 and 0.106 mm/rev.

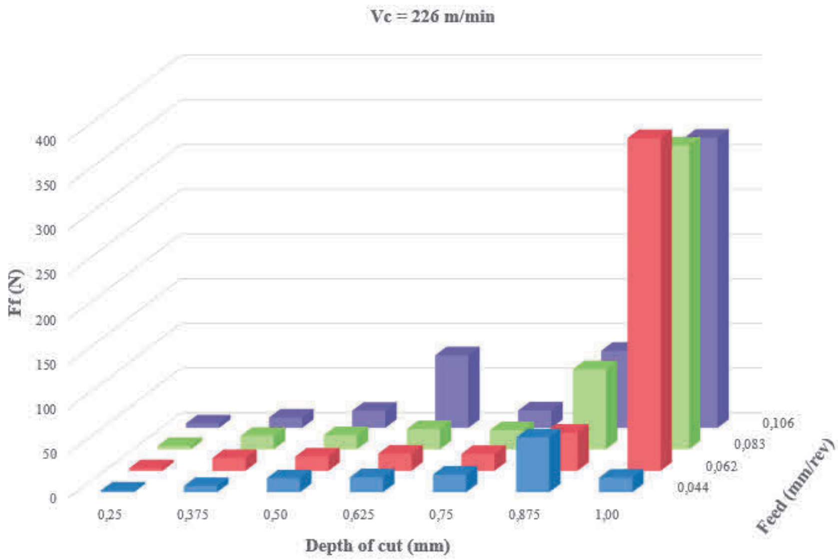


Figure 4 The influence of cutting parameters on *Ff* (N)

Figure 5 shows the results the influence of cutting parameters on the measurement of *Fp* force. The mean value of the resulting force does not exceed 110 N for depth of cut in range 0.25 ÷ 0.75 mm. Significant increase of value force was observed for ap equal 0.875 ÷ 1 mm. The highest mean value of force *Fp* (226 N) was obtained for a cutting depth equal 1 mm and feed 0.106 mm/ rev.

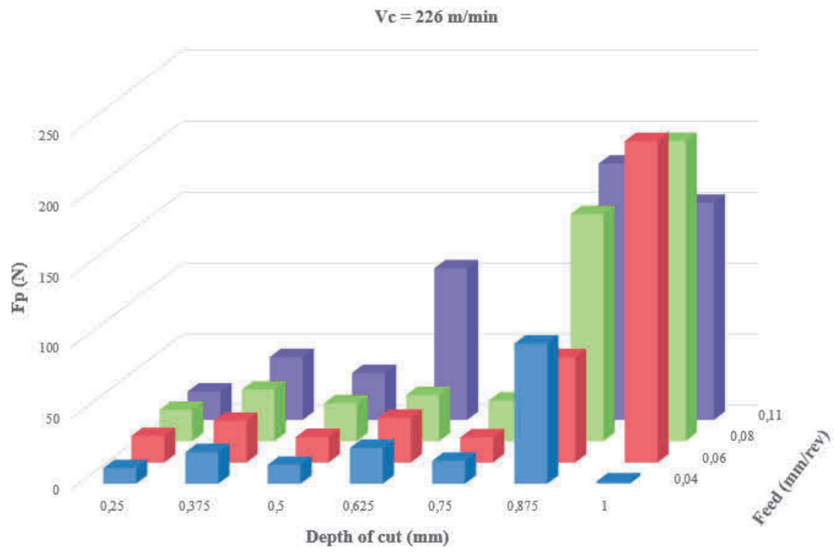


Figure 5 The influence of cutting parameters on *Fp* (N)

Figure 6 presents the results of the basic 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 0.25 to 1.0 mm, the mean value of temperatures in the range of 319 to 578 °C were obtained. Increasing the depth of cut to 0.875 and 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 = 578 °C was obtained for the turning process with *ap* = 0.625 mm and *f* = 0.106 mm/rev. Large values of standard deviation of temperature measurements indicate interference of the measurement by the temperature rise of the continuous chips.

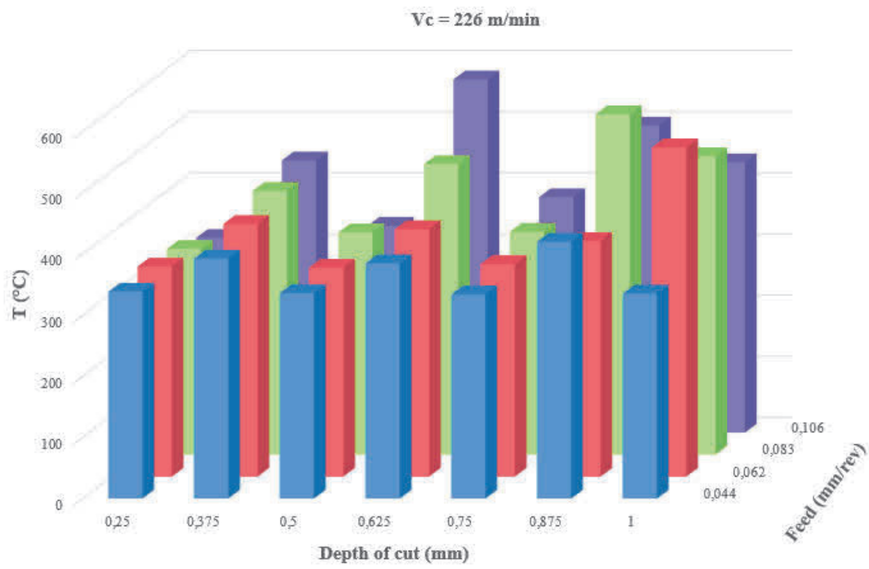


Figure 6 The influence of cutting parameters on T [°C]

4. CONCLUSION

The article is one of a series of publications relating to define a set of input factors, fixed and disruptive on the process of finishing turning shaft pins made of stainless steel. Machining of stainless steels is classified as a difficult-to-machining steel. Therefore, in order to ensure of appropriate the quality of surface roughness and productivity, it should be provide the most favorable treatment conditions during processing.

Obtained results of force and temperature measurements during cutting process allow to determine the most favorable treatment condition (depth of cut and feed at constant value of cutting speed) for the finish turning. The selection of optimal cutting parameters ensure obtaining the required quality of the geometric structure of surface and proper formation of short chips during the turning process.

Additionally, the research results of the influence of treatment conditions on the geometric structure of surface, an analysis of other surface roughness and material ratio will be performed. The final step of research will be comparing the results obtained with measurements of the surface topography. The multiple regression equations for both surface roughness and cutting forces will also be determined.

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