ISSN 0543-5846
METABK 54(1) 91-94 (2015)
UDC – UDK 669.15:620.178.1:621.9=111

INVESTIGATION OF SELECTED SURFACE INTEGRITY FEATURES OF DUPLEX STAINLESS STEEL (DSS) AFTER TURNING

Received - Primljeno: 2014-02-07
Accepted – Prihvaćeno: 2014-06-30
Original Scientific Paper – Izvorni znanstveni rad

The article presents surface roughness profiles and Abbott - Firestone curves with vertical and amplitude parameters of surface roughness after turning by means of a coated sintered carbide wedge with a coating with ceramic intermediate layer. The investigation comprised the influence of cutting speed on the selected features of surface integrity in dry machining. The material under investigation was duplex stainless steel with two-phase ferritic-austenitic structure. The tests have been performed under production conditions during machining of parts for electric motors and deep-well pumps. The obtained results allow to draw conclusions about the characteristics of surface properties of the machined parts.

Key words: duplex stainless steel, machining, turning, surface integrity, surface roughness

INTRODUCTION

Machining process is the most common process in the production of machine parts. Achieving the desired surface quality is of great importance for the functional behaviour of a part. Surface roughness and surface texture measurements of stainless steel are among the most important ones in length and angle metrology, in theory and practice. Stainless steels are subdivided by their chemical composition and metallographic structure [1, 2]. One of the stainless steel family materials are dual phase ferritic-austenitic steels, so called duplex stainless steels. The workpiece material is duplex stainless steel because this stainless steel is widely used for many industrial applications due to its unique properties. Machine tools and machining processes have to be continuously improved to fulfil the requirements necessary in the accuracy of machining [3]. Related problems to the machining process of DSS has been described by several researchers. Bouzid Saï and Lebrun [4] noted that the burnishing process produces the best quality of the surface when compared with turning or grinding. Ran et al. [5] showed the mechanical properties and corrosion resistance of the DSS designed alloys with lower production cost are better than those of AISI 316L austenitic stainless steel. Nomani et al. [6] showed the machinability tests of duplex alloys 2205 and 2507 during drilling process. They noted that both duplex alloys show a higher tendency to build-up edge and the chisel edge area had a larger wear. Braham-Bouchnak et al. [7] showed comparisons between assisted turning using variable jet pressure and conventional turning for different cutting speeds. They obtained good chip fragmentation and an improvement of tool life with high pressure water jet assistance. Krolczyk et al. showed predicting the tool life [8] and surface roughness [9], tool life [10] and cutting wedge wear [11] in the dry machining of duplex stainless steel, but those publications not presented in a comprehensive problems related to the 3D parameters of surface integrity which are important in determining corrosion resistance and fatigue crack initiation. The machinability of steels has been dealt by many researchers [12-19], but those publications didn't mention about geometrical parameters of Surface Integrity after turning process of DSS.

This paper focuses on research problems related to the surface integrity after turning by coated carbide tools. The main purpose of this study was to determine the various cutting speed as a key process factor in controlling surface integrity parameters. The aim of this study also was to present the duplex stainless steel surface roughness profiles and Abbott – Firestone curves after machining process.

METHODOLOGY OF INVESTIGATION

The purpose of the article is to present selected features of surface integrity of ferritic-austenitic steel after turning with coated sintered carbide wedges. 3D parameters of Surface Integrity have been shown and analysed for various cutting speeds. The paper presents surface roughness together with profiles and Abbott Firestone curves.

G. Krolczyk, Opole University of Technology, Faculty of Production Engineering and Logistics, Opole, Poland; P. Nieslony, Opole University of Technology, Department of Manufacturing Engineering and Production Automation; S. Legutko, Poznan University of Technology, Institute of Mechanical Technology, Poznan, Poland; S. Hloch, Intitute of Geonics Academy of Science v.v.i. Ostrava – Poruba, Czech Republic; I. Samardzic, Josip Juraj Strossmayer University of Osijek, Mechanical Engineering Faculty in Slavonski Brod, Croatia

The material under machining was 1.4462 steel (acc. to DIN EN 10088-1) with ferritic-austenitic structure containing about 50% austenite. The tensile strength was UTS = 700 MPa, Brinell hardness 290 ± 2 HB. The technical data of the cutting tool can be found in Table 1.

Table 1 **Cutting tool specification**

T1	Hardness:	Coatings: Ti(C,N) - (2 μm) (top layer)
	1350 HV3	Al_2O_3 - (1,5 μm) (middle layer)
	Grade:	TiN - (2 μm) (bottom layer)
	M25, P35	Coating technique: CVD

The cutting tool of TNMG 160408 geometry has been fixed in a clamping holder ISO-MTGNL 2020-16. Basing on the industrial recommendations and on the conclusions from our own earlier investigations [10, 11], the range of machining parameters has been selected: v_c = 50 ÷ 150 m/min, f = 0,3 mm/rev, a_p = 2 mm. The tests have been performed under production conditions on a numerically controlled lathe, FAMOT 400 CNC made by Famot – Pleszew plc. The 3D roughness parameters have been performed by means of the Infinite Focus Measurement Machine (IFM). IFM is an optical device for 3D measuring of surface parameters, for large depth of focus. The cutting edge rounding radius r_n was 0,047 mm.

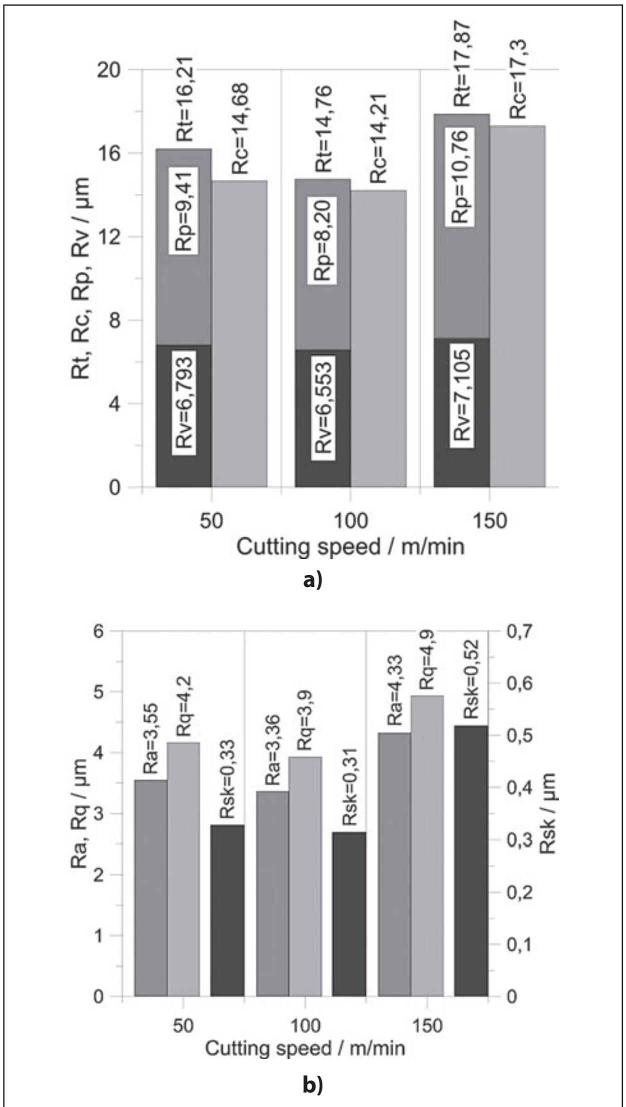

Figure 1 Surface roughness parameters: vertical ones (a) and amplitude ones (b) after duplex steel turning at various cutting speeds

SURFACE INTEGRITY ROUGHNESS MEASUREMENT RESULTS AND THEIR ANALYSIS

From the technological point of view, the correlation of SI microhardness with the surface quality is important. The assessment of the surface quality has been performed on the basis of the vertical and amplitude parameters of the surface roughness (Figure 1a and 1b, respectively). The highest values of total *Rt*, and average *Rc*, height of the profile elements have been obtained for v_c = 150 m/min. The difference between the maximum *Rt* value of 17,87 μm for v_c = 150 m/min and the minimum one (*Rt* = 14,76 μm, v_c = 100 m/min) is only 3,11 μm.

For the maximum *Rt* values (v_c = 150 m/min), however, the lowest values of microhardness have been obtained. High *Rt* is probably due to plastic flowing of the material in the cutting zone. A confirmation of the thesis can be the fact of significant increase of the profile asymmetry parameter *Rsk* with v_c = 50 and 100 m/min, which is clearly visible in Figure 1b. Plasticization of the machined material can influence the intensity of deformation of the duplex steel phases. An effect of it is low values of $HV_{0,05}$.

An interesting fact is that of obtaining low values of parameters *Ra* and *Rq* for the lower cutting speeds. For this group of technological parameters, microhardness as well as the depth of its location, is the largest [20]. When designing the technological process of duplex steel parts, one can take advantage of this feature to enlarge the thickness of the area with high SI microhardness. In this case, the process should be performed with low cutting speeds, which will allow for initial obtaining of an adequate SI layer with high value of microhardness and low roughness. A surface prepared in this way can be additionally subjected to another way of processing, e.g. burnishing.

Profiles of surface roughness after machining with various cutting speeds, together with Abbott - Firestone material contribution curves can be found in Figure 2. In this range, mainly large feed (f = 0,3 mm/rev) determines the characteristic, clearly periodical shape of the profile. For all the cutting speeds, slightly degressive Abbott - Firestone curves have been obtained.

The slopes of the analysed profiles differ in shape (Figure 2, area B, C). The most irregular slopes are those of the profile for cutting speed of 100 m/min – Figure 2, area B. A technological effect of so formed surface is, for example, a better oil adherence. This results in reduction of friction providing small initial contact surface. On the other hand, areas with significant

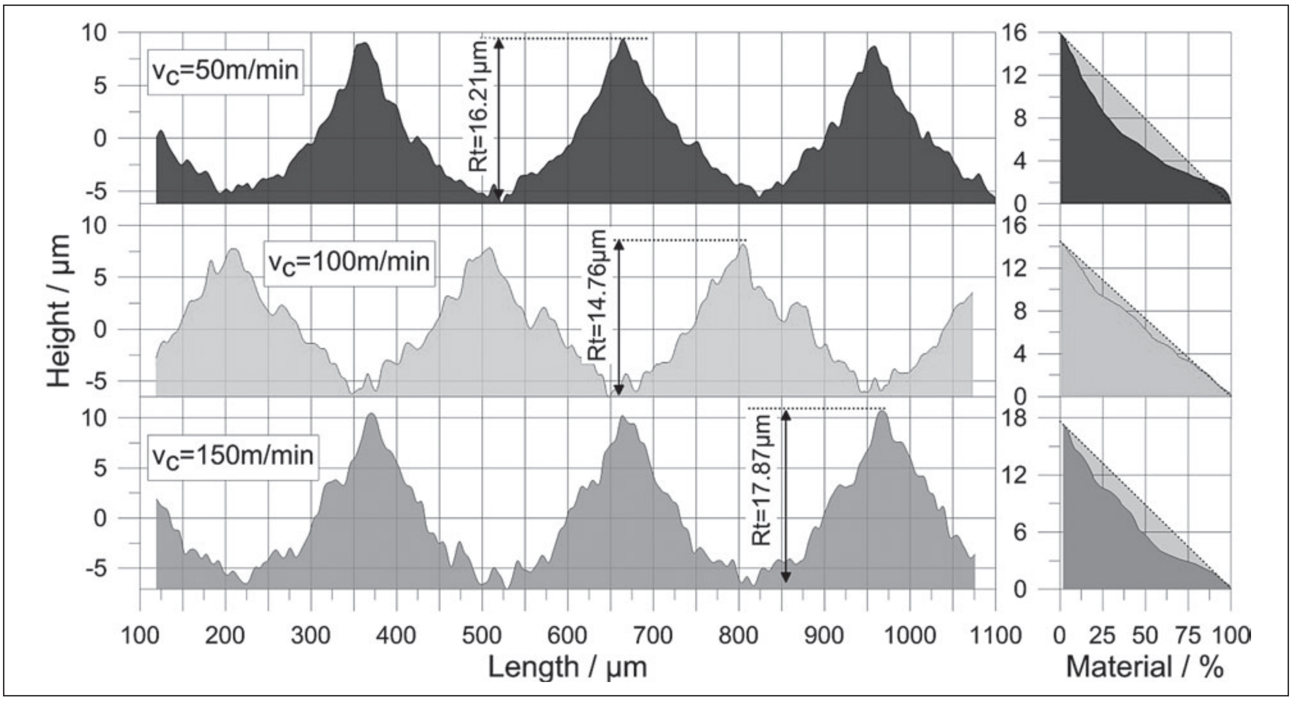

Figure 2 Roughness profiles after machining with various cutting speeds, together with Abbott - Firestone curves

values of contact stresses are obtained, which influences later utilization of machined parts manufactured in this way. Such technological parameters of machining result in arresting lubricating agents and contaminations on the surface. The fact of more uneven line of the roughness profile slope can be a premise for direct utilization of such surface to perform the processes of thermochemical treatment, i.e. carbonizing, nitriding etc. Analysing the surface in micro scale, one can see that so strongly irregular shape of the profile slopes results in much larger actual area of the object. Consequently, such area enables more heat to be released.

CONCLUSIONS

Basing on the analysis of the selected surface integrity parameters, such as measurements of the geometrical structure of duplex stainless steel surface after dry turning with a carbide wedge provided with a coating with ceramic intermediate layer, one can draw the following conclusions and make the following observations:

– The highest values of *Rt* and *Rc* have been obtained for v_c = 150 m/min. This is probably due to plasticization of the material and its flowing in the cutting zone.
– For low cutting speeds, low values of the roughness parameters *Ra* and *Rq* have been obtained. In designing the technological process of duplex steel parts, this feature can be used to enlarge the thickness of the area of low roughness. The surface prepared in this way can be additionally subjected further processes of forming SI, e.g. by burnishing.
– Cutting speed influences the roughness profile. This concerns particularly the shape of the profile slopes. It has been found that irregularity of the profile increases for higher v_c values, which can be utilized in planning the processes of thermochemical treatment. No significant influence of v_c on the shape of the Abbott - Firestone curve has been found. In this case, feed is the determining technological parameter.

REFERENCES

[1] J. Jurko, M. Gajdo, A. Panda, Study of changes under the machined surface and accompanying phenomena in the cutting zone during drilling of stainless steels with low carbon content, Metalurgija, 50 (2011) 2, 113-117.
[2] S. Hloch, J. Valícek, I. Samardzic, D. Kozak, M. Kusnerova, Classification of technical materials according to classes machinability for hydroabrasive cutting, Metalurgija, 51 (2012) 1, 125-128.
[3] G. Mijuskovic, P. Krajnik, J. Kopac, Improvement of positional accuracy of precision micro milling center using pitch error compensation, Tehnički Vjesnik - Technical Gazette, 20 (2013) 4, 629-634.
[4] W. Bouzid Saï, J. L. Lebrun, Influence of Finishing by Burnishing on Surface Characteristics, Journal of Materials Engineering and Performance, 12 (2003) 1, 37-40.
[5] Q. Ran, J. Li, Y. Xu, X. Xiao, H. Yu, L. Jiang, Novel Cu-bearing economical 21Cr duplex stainless steels, Materials and Design, 46 (2013) 758-765.
[6] J. Nomani, A. Pramanik, T. Hilditch, G. Littlefair, Machinability study of first generation duplex (2205), second generation duplex (2507) and austenite stainless steel during drilling process, Wear, 304 (2013), 20-28.
[7] T. Braham-Bouchnak, G. Germain, P. Robert, J. L. Lebrun, High pressure water jet assisted machining of duplex steel: machinability and tool life, International Journal of Material Forming 3 (2010), 507-510.

[8] G. Krolczyk, M. Gajek, S. Legutko, Predicting the tool life in the dry machining of duplex stainless steel, Eksploatacja i Niezawodnosc – Maintenance and Reliability, 15 (2013) 1, 62-65.
[9] G. Krolczyk, S. Legutko, M. Gajek, Predicting the surface roughness in the dry machining of duplex stainless steel (DSS), Metalurgija, 52 (2013) 2, 259-262.
[10] G. Krolczyk, M. Gajek, S. Legutko, Effect of the cutting parameters impact on tool life in duplex stainless steel turning process, Tehnički Vjesnik - Technical Gazette, 20 (2013) 4, 587-592.
[11] G. Krolczyk, S. Legutko, P. Raos, Cutting wedge wear examination during turning of duplex stainless steel, Tehnički Vjesnik - Technical Gazette, 20 (2013) 3, 413-418.
[12] J. Madl, V. Razek, V. Koutny, J. Kafka, Surface integrity in notches machining, Manufacturing Technology, 13 (2013) 2, 188-193.
[13] J. Kenda, G. Kermouche, F. Dumont, J. Rech, J. Kopac, Investigation of the surface integrity induced by abrasive flow machining on AISI D2 hardened steel, International Journal of Materials and Product Technology, 46 (2013) 1, 19-31.
[14] N. Guillemot, B. K. Mawussi, C. Lartigue, R. Billardon, A first approach to characterize the surface integrity generated by ball-end finishing milling, International Journal of Advanced Manufacturing Technology, 64 (2013) 1-4, 269-279.
[15] T. Rajmohan, K. Palanikumar, J. P. Davim, Analysis of Surface Integrity in Drilling Metal Matrix and Hybrid Metal Matrix Composites, Journal of Materials Science and Technology, 28 (2012) 8, 761-768.
[16] M. Dogra, V. Sharma, A. Sachdeva, N. M. Suri, Tool life and surface integrity issues in continuous and interrupted finish hard turning with coated carbide and CBN tools, Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture 226 (2012) 3, 431-444.
[17] M. Gostimirović, P. Kovač, D. Ješić, B. Škorić, B. Savković, Surface layer properties of the workpiece material in high performance grinding, Metalurgija 51 (2012) 1, 105-108.
[18] U. Zupanc, J. Grum, Surface integrity of shot peened aluminium alloy 7075-T651, Strojniski Vestnik/Journal of Mechanical Engineering, 57 (2011) 5, 379-384.
[19] J. Novakova, L. Petrkovska, J. Brychta, R. Cep, L. Ocenasova, Influence of high speed parameters on the quality of machined surface, World Academy of Science, Engineering and Technology, 56 (2009), 274-277.
[20] G. Krolczyk, P. Nieslony, S. Legutko, Microhardness and Surface Integrity in turning process of duplex stainless steel (DSS) for different cutting conditions, Journal of Materials Engineering and Performance, 23 (2014) 3, 859-866.

Note: The responsible translator for English language is lecturer from Poznan University of Technology, Poland