S. HLOCH, J. HLAVÁČEK, K. VASILKO, J. CÁRACH, I. SAMARDŽIĆ, D. KOZAK, I. HLAVATÝ, J. J. ŠČUČKA, KLICH, D. KLICHOVÁ

ISSN 0543-5846
METABK 53(4) 537-540 (2014)
UDC – UDK 669.295.004.6:621.924.9:622.752=111

ABRASIVE WATERJET (AWJ) TITANIUM TANGENTIAL TURNING EVALUATION

Received – Prispjelo: 2013-12-05
Accepted – Prihvaćeno: 2014-04-15
Original Scientific Paper – Izvorni znanstveni rad

The paper deals with abrasive waterjet titanium tangential turning. Titanium grade 3 with a diameter of 55 mm was used as an experimental material. Technological conditions of turning tests were the same by gradually changing value of traverse speed (v_f = 1,5; 3; 4,5; 6; 7,5 mm·min^{-1}). Experiment tests were performed by using continuous abrasive waterjet of pressure p = 400MPa, by rotation n = 60 rpm of workpiece. The abrasive particles (Barton Garnet) were fed to the waterjet in the amount of 0,4 kg·min^{-1}. It was determined that acceleration of traverse speed did not increase the surface profile parameters.

Key words: titanium, abrasive waterjet turning, traverse speed

INTRODUCTION

Titanium and the titanium alloy are classed as hard machining materials, and the material removal differs from other alloy machining. Material removal speed is lower than in steel machining. Blunting tool durability is influenced by the size of flank wear and cutting edge deformation. Cutting power is smaller than in machining of pure iron and nickel. Currently, cutting speed is under the limit of 60 m·min^{-1}. It is necessary to take into account creation of tool vibration, which is created by uneven plastic deformations. Unstable deformation character is obviously related to segmentation of titans chip (Figure 1). That process is influenced by strength reduction and hardening deformation. Poor heat conductivity of titanium workpiece causes lines creation of concentrated skid.

The heat energy is concentrated in those lines. Adhesion occurs by machining of titanium alloy and these effects cause high intensity of tool depreciation.

High speed waterjet is used to increase the tool durability, ensuring chip breaking, friction reducing and cooling (Figure 2). Habak and Lebrun [1] studied this method by using conventional turning of stainless steel compared with dry turning.

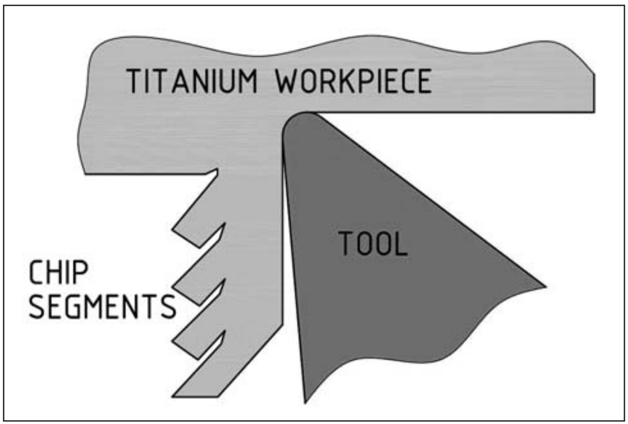

Figure 1 Creation of Chip Segments by Machining

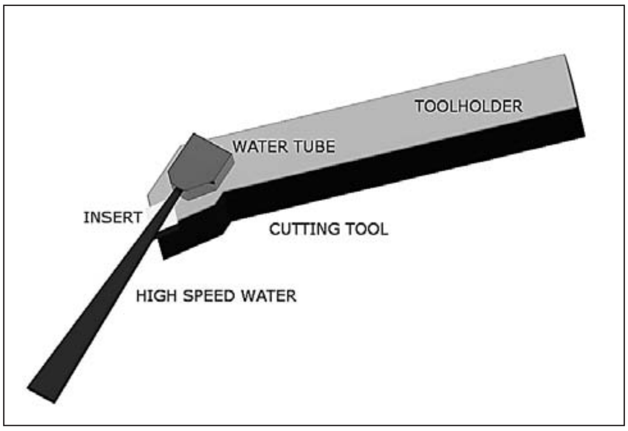

Figure 2 Utilization of High-speed Waterjet [1]

MATERIALS AND METHOD

The 2D X-Y cutting table PTV WJ2020-2Z-1xPJ with inclinable cutting head, specially designed for cutting with water and abrasive water jet was used in tests (Figure 3). The water pressure was generated by PTV75-60 pump with two pressure intensifiers (operating pressure of 40 ÷ 415 MPa, max. flow of 7,8 l·min^{-1} at 415 MPa). Turned traces were created at pressure p = 400 MPa using focusing tube with a diameter d_f = 1,02 mm.

S. Hloch, K. Vasilko, J. Cárach, D. Lehocká Faculty of Manufacturing Technologies, with a seat in Prešov, Prešov, Slovak Republic
S.Hloch, J. Hlaváček, J. Klich, D. Klichová Intitute of Geonics Academy of Science v.v.i. Ostrava – Poruba, Czech Republic
I. Samardžić, D. Kozak Josip Juraj Strossmayer University of Osijek, Mechanical Engineering Faculty in Slavonski Brod, Croatia
I. Hlavatý Faculty of Mechanical Engineering, VŠB-Technical University of Ostrava

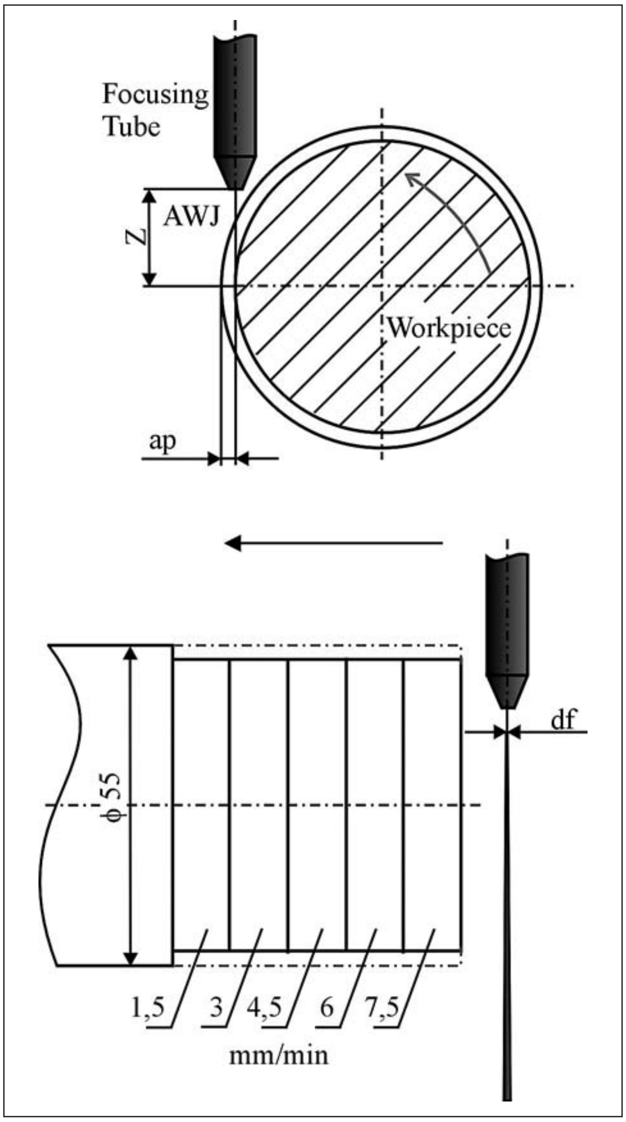

Figure 3 Experimental set-up of AWJ

An offset radial mode was used to set the right position of the workpiece and the AWJ. The AWJ turning was realized on the cutting table of Geonics Academy of Science of Czech Republic, v.v.i., Ostrava Poruba. The titanium workpiece was clamped between the jaws of the Festo company power chuck.

The method of AWJ down turning was applied.

Barton Garnet was used as abrasive particles.

The size of garnet grains was approximately 0,18 to 0,35 μm (MESH 80). [2]

Experimental conditions are listed in the Table 1. The material removal was done as microerosion process of abrasive particles, influencing high-speed water and rotating workpiece surface. [3]

By AWJ cutting and machining, this process was realized in three mechanisms (microchip formation, plowing and rubbing), which took place through shear deformation. It was very important to set up many technological factors for right material removal. [4]

The reaction by AWJ turning of titanium workpiece was very interesting. Abrasive garnet particles dispersed in the high-speed water impact on the titanium surface.

Table 1 **Experiment set-up**

Factors	Unit	Value	Dimension
Pressure	p	400	MPa
Orifice diameter	d_o	0,33	mm
Focusing tube diameter	d_f	1,02	mm
Depth of cut	a_p	2	mm
Stand off distance	z	10	mm
Abrasive mass flow rate	m_a	0,4	$kg \cdot min^{-1}$
Workpiece diameter	d_w	55	mm

Figure 4 AWJ Turning process of Titanium Workpiece

High friction increased temperature of titanium particles, causing it to create sparks and chips burning (Figure 4). It is known that titanium has been reacting to fine machining (chips ignition) and that such burning is not possible to be extinguished with water.

RESULTS

The surface roughness created by continuous waterjet was measured by an optical profilometer MicroProf FRT, using sensor SEN 000 03 (Figure 5) at the Institute of Geonics AS CR, v.v.i. The 3D plot of surface was compiled from lines for sample with the following measurement parameters: measurement area 37 x 5,5 mm, vertical resolution 4 μm, accuracy 1 μm, linearity 0,1 %, lateral resolution 5 μm, number of measurement traces 1111 Table 2.

Table 2 **Measurement Conditions**

Form removal	Line
Noise filter cut-off/ *ls*	25 μm
ISO 4287	
Cut-off wavelength,/*lc*	2,5 mm
Number of cut-offs	1
Evaluation length	2,5 mm

This profilometer is distinguished by high reliability and strong versatility. It can be adapted to many applications due to its modular construction.

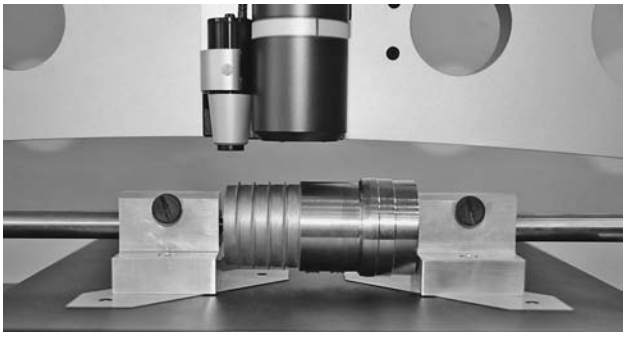

Figure 5 Profilometer MicroProf FRT

Measurement results showed irregularity of roughness, where the values did not increase along with the increased traverse speed v_f (Table 3).

Table 3 Values of Measured Roughness

v_f /mm·min^{-1}	*Ra*/µm	*Rq*/µm	*Rz*/µm
1,5	6,984	8,859	47,764
3	5,438	6,583	31,988
4,5	10,687	12,686	60,849
6	7,317	8,806	45,211
7,5	8,308	11,191	57,879

The following Figures 6-10 show surface after abrasive water jet turning. Surface profile parameters (Table 3) were obtained within the white section.

The 3D surface image (Figure 11) was made by using laser confocal microscope Olympus LEXT OLS 3100 including surface texture in real color (Figure 12).

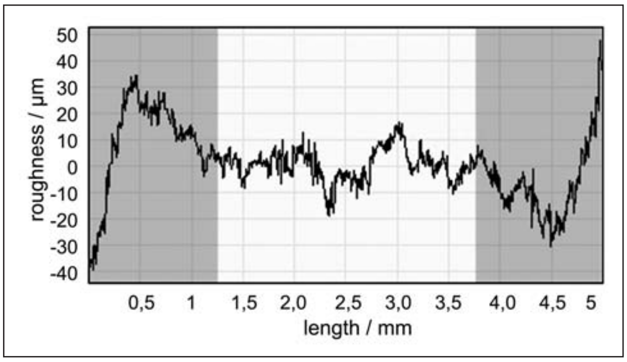

Figure 6 Surface Roughness profile created as v_f = 1,5 mm·min^{-1}

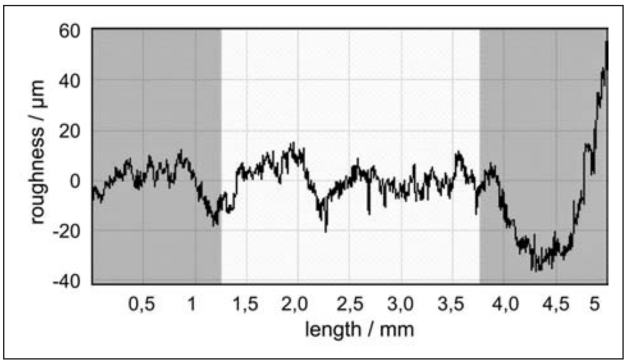

Figure 7 Surface Roughness profile created as v_f = 3 mm·min^{-1}

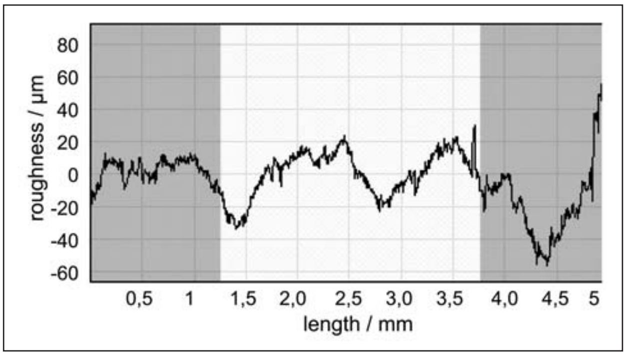

Figure 8 Surface Roughness profile created as v_f = 4,5 mm·min^{-1}

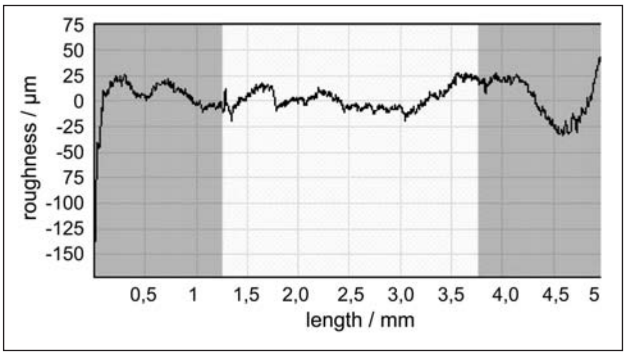

Figure 9 Surface Roughness profile created as v_f = 6 mm·min^{-1}

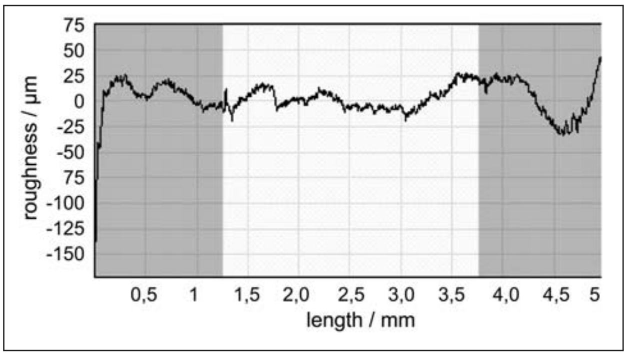

Figure 10 Surface Roughness profile created as v_f = 7,5 mm·min^{-1}

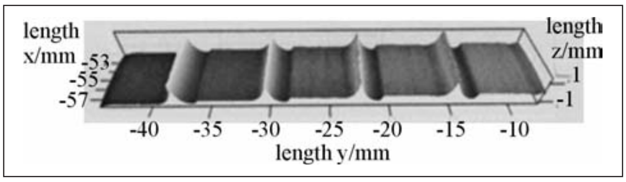

Figure 11 3D View of Titanium Surface Spread in Straightaway

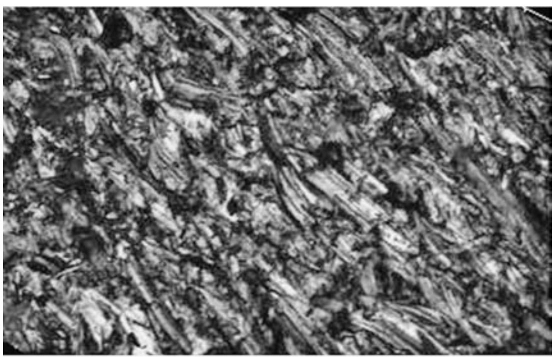

Figure 12 Machined Titanium surface using AWJ, (Zoom 20 x)

CONCLUSIONS

Testing of roughness of titanium workpiece surface with a diameter of 55 mm measured by the AWJ technology and by the selected experimental conditions resulted in conclusion that the increase of traverse speed did not influence roughness rectilinear. The surface roughness was higher by traverse speed of 1,5 $mm \cdot min^{-1}$ than by 3 $mm \cdot min^{-1}$ and 4,5 $mm \cdot min^{-1}$ and 6 $mm \cdot min^{-1}$.

As of Figure 11, it was determined that the increase of traverse speed caused diameter change. Abrasive particles that dispersed in the high-speed water had less time for material removal.

Machining of extra hard materials is an up-to-date topic of research and many authors [5 - 7] addressed the problem so far. Królczyk et al. [5] studied wear of tool and durability in machining of stainless steel. It was concluded that the increase of cutting speed increased the wear intensity of tool cutting edge by turning.

There is a need to perform further research into machining by using the abrasive waterjet method and turning the titanium workpiece, since this technology is offering a real possibility for extra hard materials machining.

Acknowledgement

The research is supported by the Slovak Research and Development Agency under the contract No. APVV-207-12. Experiments were supported by the Institute of clean technologies for mining and utilization of raw materials for energy use, reg. no. CZ.1.05/2.1.00/03.0082, as well as by the Research and Development Innovations Operational Programme financed by the Structural Funds of the European Union and the Czech Republic state budget, within the long-term conceptual development of research institution RVO: 68145535.

The authors would like to thank the Institute of Geonics, Academy of Science of the Czech Republic, v.v.i., Ostrava Poruba, Czech Republic, for providing support to experiment realization.

REFERENCES

[1] M. Habak, J. Lebrun An experimental study of the effect of high-pressure water jet assisted turning (HPWJAT) on the surface integrity In: International Journal of Machine Tool & Manufacture 51 (2011) 661-669.

[2] M. Karková, L. Sobotová Abrasive materials used in AWJ cutting of material technology, Katedra environmentalistiky, Transfer inovácií 25/2013. URL: http://www.sjf.tuke.sk/transferinovacii/pages/archiv/transfer/25-2013/pdf/146-149.pdf. (28-Sep-2013).

[3] R. Manu, R.N. Babu, An erosion-based model for abrasive waterjet turning of ductile materials In: Science Direct, Wear 266 (2009), 1091-1097.

[4] D.Arola, M. Ramulu Material removal in abrasive waterjet machining of metals Surface integrity and texture In: Science Direct, Wear 210 (1997), 50-58.

[5] G. Królczyk, S. Legutko, P. Raos Cutting wedge wear examination during turning of duplex stainless steel In: Technical Gazette, 20 (2013), 3, 413-418.

[6] G. Królczyk, M. Gajek, S. Legutko Effect of the cutting parameters impact on tool life in duplex stainless steel turning process In: Technical Gazette, 20(2013), 3, 587-592.

[7] Šimunovic, G., Šimunović, K., Šarić, T. et al. Modelling and simulation of surface roughness in face milling In: International Journal of Simulation Modelling, 12 (2013), 3, 141-153

Note: The responsible person for English language is prof. Martina Šuto, M.A., J.J. Strossmayer University of Osijek.