Primary research on electrochemical assistance of microcutting process

S. Skoczypiec[1], M. Grabowski[1], A. Ruszaj[1]
[1]*Cracow University of Technology, Faculty of Mechanical Engineering, Production Engineering Institute, Poland*

skoczypiec@m6.mech.pk.edu.pl

Abstract

In the paper the conception of the process and test stand design for electrochemically assisted microturning was described. For investigated process, the most important characteristic is relation between electrochemical assistance parameters and the thickness of the passive layer. Therefore the primary results of passive layer thickness measurement were also presented.

1 Introduction

In the group of methods dedicated for machining of technological equipment, MEMS parts, functional prototypes and tools for micro-casting and micro-forming special attention is paid for application of microcutting and unconventional processes such as the laser beam, electrodischarge and electrochemical machining. In case of microcutting the main problem occurring during machining is related to the size effect [3, 4, 5]. Significant forces appearing in the machining area limit application for machining of 3D parts made of soft materials and dimensions > 100 micrometers. One of the solutions to overcome this problem and achieve high performance for microcutting process is application of electrochemical assistance. This is typical hybrid process, where microcutting directly removes the material while the electrochemical passivation is changing the conditions of cutting, by decreasing mechanical properties of machined material [2]. On the workpiece surface the thin metal oxide layer is created (thickness < 1 micrometer). This layer is brittle and softer than the core material, so can be removed with use of relatively smaller forces [1]. It is worth to underline, that cutting force decrease is possible when thickness of removed material is correlated with thickness of created oxide layer. Based on Pourbaix diagram, one can state, that the passive layer thickness depends on the electrolyte pH and voltage between the workpiece and cathode tool. Thus, for investigated process, the most important characteristic is relation between electrochemical assistance parameters and the thickness of the passive layer. Analysis of electrochemical assistance technical feasibility leads to the conclusion, that microturning is the most perspective way to take advantages of presented conception. The scheme of such a process was presented in figure 1.

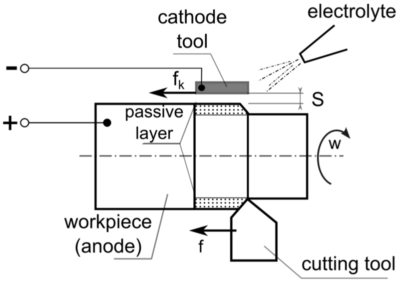


Figure 1: Scheme of electrochemically assisted microturning : S – interelectrode gap; f, f_k – cutting tool and cathode feed rate ($f = f_k$), w – rotational speed

3. Test stand design

Test stand design should include considerations about machining allowance of thickness less than 1 µm for shafts with diameter < 1 mm. The main part of test stand consist of (figure 2):

- vibroisolated working table,
- JÄGER, type Z33-M0100.02 S1 high speed spindle with max rotation speed 100000 rpm (to obtain the cutting speed in range of tens mm/min the rotation speed has to be > 50000 rpm),
- tool – workpiece motion system, consist of manual micrometer stages (for initial tool positioning), based on DC motor PI micro-translation stages for tool feed movements (minimal incremental motion 50 nm, repeatability 100 nm, maximal speed 1,5 mm/s) and one axis linear piezo nanopositioner for main cutting movement (closed-loop travel 100 µm with resolution 2 nm),
- tooling for electrochemical assistance (manual translation stage with electrode tool, current conduit system and current supplier),
- system for cutting force analysis (as results from forces analysis, the cutting forces are one order less than in traditional cutting process, what cause some difficulties

in selection of proper force sensor, so proper selection needs some primary tests). Due to electrochemical impact the test stand was built with use of corrosive resistant materials.

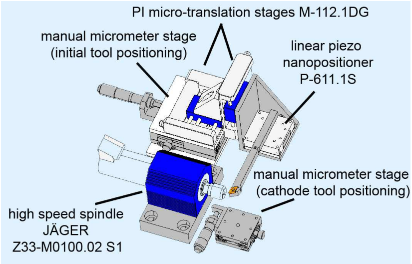
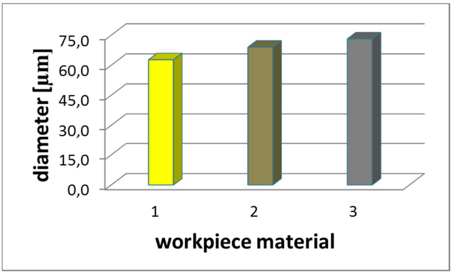


Figure 2: 3D scheme and photography of microturning test - stand

4. Results of primary research

The experimental research was focused on estimation of the boundary shaft diameter, when the electrochemical assistance should be applied. With application of the microscope and CCD camera the cutting process was monitored and the diameter, when the shaft starts to bend significantly was registered. Research was carried for brass, 304 stainless steel and titanium alloy WT3. The research realized as a straight turning and the cutting parameters for all materials were as follows: cutting speed: 10 m/min, feed rate 1,2 mm/min and cutting depth: 1 μm. For each material five repetition were applied. The results are presented on the figure 3.



1 - brass

2 - tungsten

3 -stainless steel

Figure 3: Results of the boundary shaft diameter estimation (diameter when the electrochemical assistance should be applied)

As was mentioned above, the success of cutting and electrochemical combination depends on the knowledge of the passive layer thickness. Therefore, the thickness of the layers was measured with ellispometry technique. The layers were formed on the flat surface of 304 steel samples installed in the special ECM chamber with forced electrolyte flow (water solution of *7%* $NaNO_3$). Distance between anode and cathode was fixed *0,25 mm* and voltage was switched on for *1 min*. The results of passive layer thickness measurement are as follows: for $U = 3\ V$- $g = 40\ nm$, for $U = 5\ V$ - $g = 70\ nm$.

5. Conclusions

The paper presents the conception of electrochemical assistance of microcutting process. In order to carry out the experimental research, the test stand was designed. From primary research of microturning results, that the electrochemical assistance should be considered for tool diameter less than *100 μm.* and as results from primary measurements of passive layer thickness, the cutting depth should be in range of *100 nm*. The further research should be focused on optimization of passive layer formation process and determination of such layer mechanical properties (i.e. microhardness). Such knowledge gives base to research of passive layer cutting process.

Acknowledgments

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References:

[1] *United States Patent no. 5,967,347:* Micro cutting method and systems, *1999.*

[2] Kozak J., Oczoś K.E. Selected problems of abrasive hybrid machining. *Journal of Materials Processing Technology. vol. 109, 2001, str. 360-366.*

[3] Vollertsen F., Biermann D, Hansen H.N., Jawahir I.S., Kuzman K. : Size effects in manufacturing of metallic components. *CIRP Annals - Manufacturing Technology 58 (2009) 566–587.*

[4] Cuba Ramos A., Autenrieth H, Strauß T. Deuchert M., Hoffmeister J., Schulze V.: *Characterization of the transition from plugging to cutting in micro machining and evaluation of the minimum thickness of cut. Journal of Materials Processing Technology, Vol. 212, Issue 3, 2012, str. 594–600.*

[5] Vinayagamoorthy R, Anthony Xavior M. A review on micro turning process International Journal of Current Research Vol. 3, Issue, 11, pp.174-179, October, 2011.