Precision Turning with Localized Anodic Dissolution

M. Hackert-Oschätzchen[1], G. Meichsner[2], M. Zinecker[1], A. Schubert[1,2]
[1]*Chair Micromanufacturing Technology, Faculty of Mechanical Engineering, Chemnitz University of Technology, 09107 Chemnitz, Germany*
[2]*Fraunhofer Institute for Machine Tools and Forming Technology, 09126 Chemnitz, Germany*

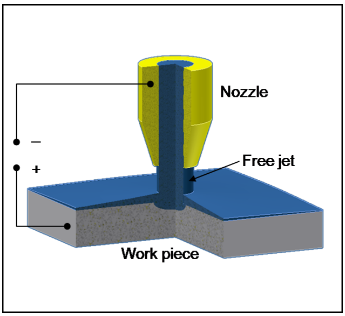
matthias.hackert@mb.tu-chemnitz.de

Abstract

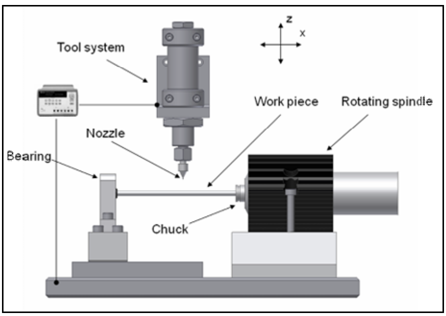
The basic principle of Electrochemical Machining is an anodic dissolution of metallic work pieces at their interface to a liquid ion conductor, called electrolyte, under the influence of electric charge transport. Electrochemical Machining with closed electrolytic free jet (Jet-ECM) is a new procedure which applies high current densities with a high degree of local removal, high localization of erosion and high surface quality [1]. Starting from this point machining of rotating work pieces by help of Jet-ECM is investigated [2]. Therefore a Jet-EC Turning prototype system was developed at Chemnitz University of Technology. In this study experimental investigations for a characterization of the influence of different process parameters on the Jet-EC turning result are presented.

1 Introduction

In Jet-ECM the electric current between the anodic work piece and the cathodic tool is supplied by an electrolyte jet which is ejected from a small nozzle, like illustrated in figure 1a.



a) Scheme of Jet-ECM



b) Scheme of the Jet-EC Turning system

Figure 1: Jet-ECM for precision turning

Compared to other EC processes, the main advantage is the restriction of the electric current to a limited area by the jet, which localizes the dissolution process [3,4]. Based on this localized anodic dissolution, which can easily be controlled by setting the electric current and the nozzle position, micro structured surfaces and complex three-dimensional micro geometries can be machined [4]. Supplying a high amount of fresh electrolyte offers the possibility to use continuous direct current with mean current densities up to 1000 A/cm². Therefore higher local removal rates can be achieved in comparison to EC processes which are based on pulsed electrical current.
Shibuya et al. transferred 2010 the Jet-ECM principle from the machining of plane work pieces to the manufacturing of rotation-symmetric components [2]. They developed a turning process using an electrolyte jet with narrow rectangular cross section (electrolyte jet turning). A specific feature is the use of a jet whose width is larger than the work piece diameter to improve the machining speed. Disadvantage of this approach is the limitation of the accuracy.
In cooperation between the Chair Micromanufacturing Technology at Chemnitz UT and the Fraunhofer Institute for Machine Tools and Forming Technology Chemnitz the potential of Jet-ECM for the precision turning of rotating work pieces is presently investigated. A Jet-ECM prototype system was developed (figure 1b) which is characterized by the use of a cylindrical electrolyte jet. Advantages are high current densities with high local removal rates. Excellent surface qualities of the machined areas can be obtained.

2 Design of experiments

To perform experimental investigations, which should demonstrate the potential of Jet-ECM for the precise machining of rotating work pieces, the existing Jet-ECM prototype facility was modified. Especially components for a realization of the work piece rotation like motor spindle, chuck and ball-bearing were installed and adjusted. A photo of the new experimental setup of the Jet-EC turning system is shown in figure 2.
To determine the influence of different process parameters on the machining results a multitude of experiments were performed. In particular, profile turning and cylindrical turning processes were investigated in this study. The machining time was

varied for profile turning. For cylindrical turning, different nozzle velocities in axial direction to the work piece (cylindrical turning) were analyzed. The parameters for the experiments are summarized in table 1.

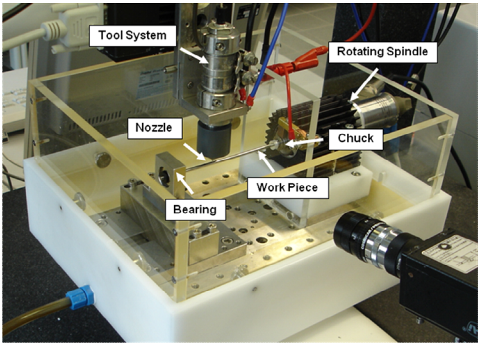


Figure 2: Photo of the experimental setup for the Jet-EC turning system

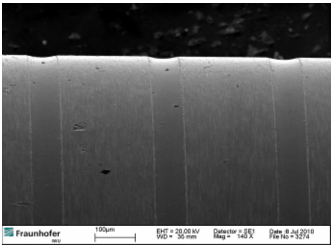
Table1: Experimental Parameters

Symbol	Parameter	Value
General:		
	Work piece material	Stainless steel shaft 1.4301 (Ø 3 mm)
	Electrolyte	Sodium nitrate
c	Mass friction sodium nitrate	30 %
a	Working distance	100 µm
U	Electrical voltage	56 V
n	Rotation speed	5000 1/min
Profile Turning:		
d	Nozzle inner diameter	50 µm
dV/dt	Pump delivery rate	2.5 ml/min
t	Process time	10 s; 20 s; 30 s; 40 s
Cylindrical Turning:		
d	Nozzle inner diameter	100 µm
dV/dt	Pump delivery rate	5.0 ml/min
v	Nozzle velocity	2 µm/s; 10 µm/s
z	Number of crossings	1; 5

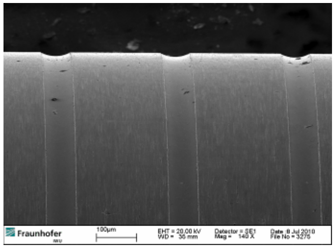
3 Experimental results

For a first qualitative analysis of the machining results an examination of SEM images was carried out. In addition a Hyperion measurement system with autofocus sensor from the OPM-Messtechnik company was used to analyze the dimensions of the realized structures and the surface parameters of the eroded areas.

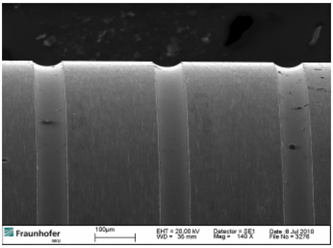
Figure 3 shows SEM images of the machining results for profile turning processes. In the experiments the process time was varied from 10 s to 40 s and the nozzle was not moved during the process. Similar to the machining of flat surfaces grooves were fabricated. The depths of the profiles rise from about 7 µm for a process time of 10 s (figure 3a) to approximately 21 µm for 40 s machining time (figure 3d). The widths amount to about 75 µm for the performed experiments. An increasing of the process time does not lead to a widening of the profiles.



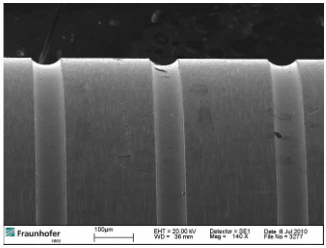
a) Process time: 3 x 10 s



b) Process time: 3 x 20 s



c) Process time: 3 x 30 s

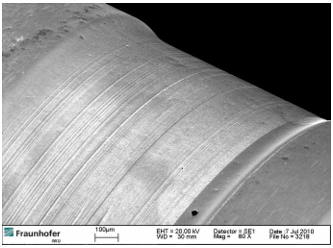


d) Process time: 3 x 40 s

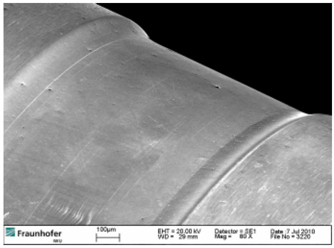
Figure 3: SEM images of the machining results after profile turning

A high reproducibility of the machining results is obvious. An analysis of the surface characteristics within the structures offers a surface roughness Rz of about 0.6 µm for all profiles. Accordingly, the roughness of the profiles is much lower than for the unmachined areas where Rz > 1.6 µm.

The SEM images of the machining results for the cylindrical turning processes are shown in figure 4. The velocity of the nozzle in axial direction to the work piece was varied from 2 µm/s to 10 µm/s. To keep to process time constant the number of nozzle crossings was increased from 1 to 5. In both cases an electrochemical removal of about 53 µm in depth was achieved over a length of 1000 µm. By comparing the SEM images it can be seen that with higher nozzle velocities a smoother surface was realized (figure 4b). Quantitative analysis of the surface parameters showed that the surface roughness Rz for the machined area in figure 4a is about 1.4 µm whereas in figure 4b a roughness Rz of approximately 1.0 µm was obtained.



a) v = 2 µm/s; n = 1



b) v = 10 µm/s; n = 5

Figure 4: SEM images of the machining results after cylindrical turning

4 Summary

In the present work a novel procedure based on electrochemical machining with closed electrolytic free jet (Jet-ECM) was demonstrated for the precision turning of rotating work pieces. Experiments were performed to investigate the effect of different process parameters on the machining results. Especially for profile turning and cylindrical turning processes the parameters machining time and nozzle velocity were in focus of this research. It can be derived that Jet-EC turning is a suitable technology for precision machining of rotating work pieces.

Acknowledgment

These investigations were supported by the Federal Ministry of Economics and Technology on account of a decision of the German Bundestag.

References:

[1] M. Hackert, G. Meichsner, A. Schubert. Generating plane and microstructured surfaces applying Jet Electrochemical Machining. *In: Proceedings of Fifth International Symposium on Electrochemical Machining Technology*, 2009, ISBN 978-3-8396-0076-4.

[2] N. Shibuya, S. Watanabe, M. Kunieda, N. Iwamot. Study on Electrolyte Jet Turning. *Proceedings of the 16th International Symposium on Electromachining*, 347-350, 2010. ISBN 978-7-313-05630-6.

[3] M. Hackert, G. Meichsner, A. Schubert. Fast Micro Structuring with Electrolyte Jet Machining. *In: Proceedings of Fourth International Symposium on Electrochemical Machining Technology*, 1:123-128, 2007. ISBN 978-3-00-022770-7.

[4] W. Natsu, T. Ikeda, M. Kunieda. Generating complicated surface with electrolyte jet machining. *Precision Engineering*, 31:33-39, 2007.