Micro Turning with Closed Electrolytic Free Jet

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Abstract

The Electrochemical Machining (ECM) with a closed electrolytic free jet (Jet-ECM) is an innovative micro manufacturing technology. Based on anodic dissolution micro structured surfaces and complex three-dimensional geometries can be machined [1, 2]. In comparison to other EC methods the main advantage is the restriction of the electric current to a limited area by the jet [2, 3]. In this study the application of Jet-ECM for the machining of rotating work pieces is investigated. Therefore a Jet-EC Turning prototype system was developed and realized. In addition, different turning procedures were investigated in experiments, to verify the functionality of micro turning with Jet-ECM.

1 Introduction

Electrochemical Machining is used for the manufacturing of work pieces with high precision and surface quality. An anodic dissolution of metallic work pieces at their interface to a liquid ion conductor, called electrolyte, under the influence of electric charge transport is the basic principle of all applications of Electrochemical Machining [4]. Electrochemical Machining with a closed electrolytic free jet is an unconventional electrochemical technology, which applies high current densities with a high local material removal, high localization of erosion and high surface qualitiy [4]. 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 nozzle like shown in figure 1.

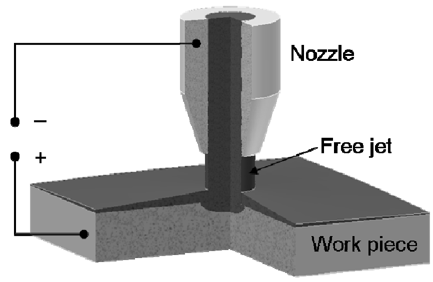


Figure 1: *Scheme of Jet-ECM*

Due to the restriction of the electric current to a limited area by the jet the local anodic dissolution can easily be controlled. By use of the jet enough fresh electrolyte is supplied, which contains a high amount of ions and is free of reaction products. This offers the use of continuous direct current with mean current densities up to 1000 A/cm². High local removal rates are achieved, compared to other EC processes.

Up to now Jet-ECM was only investigated to machine plane work pieces. At first Shibuya described a machining method which conduct turning processes using an electrolyte jet with narrow rectangular cross section (electrolyte jet turning) [5]. The width of the applied jet was larger than the work piece diameter to improve the machining speed.

Currently the potential of Jet-ECM for the machining of rotating work pieces is investigated at the Chair Micromanufacturing Technology at Chemnitz University of Technology. The intention is a development of a novel turning procedure based on the existing Jet-ECM principle. In contrast to Shibuya's investigations a small cylindrical electrolyte jet is used which enables high current densities with high local removal rates and excellent surface qualities of the eroded areas.

2 Design of the Jet-EC Turning system

In addition to the traditional components of Jet-ECM like 3-axes-system, cathodic and anodic electrodes, electrolyte and power supply, elements for the rotation of the work piece are required. A rotary drive, a mounting attachment and a counter bearing for the work piece are essential components, which have to be integrated. The geometry of the work pieces was defined to be up to 5 mm in diameter and up to 150 mm in length. Demands for the new components are corrosion resistance against the applied electrolytes and a supply of an anodic contact for the work piece. Furthermore, the components have to be protected towards an electrochemical removal by qualified insulation.

The concept for an experimental setup is shown in figure 2.

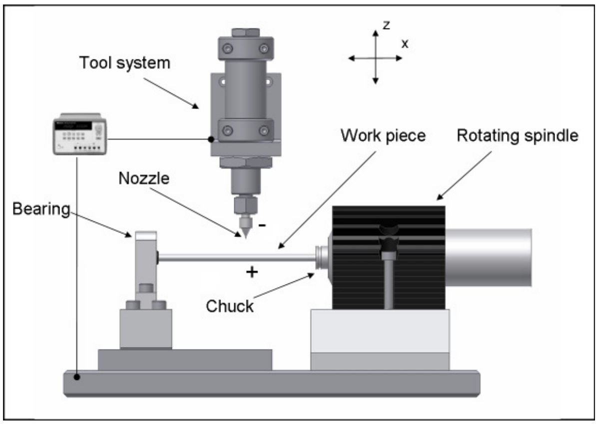


Figure 2: *Scheme of the Jet-EC Turning prototype system*

The nozzle and the mounting attachment are connected with a power supply. The electrolyte is supported through the nozzle. A rotating spindle provides a rotation movement of the chucked work piece. Additionally the work piece is guided by a counter bearing, to guarantee a high concentricity of rotation.

3 Experimental verification

Experiments were executed to demonstrate the potential of Jet-ECM for the machining of rotating work pieces. To perform the experiments the existing Jet-

ECM prototype facility was rebuilt according to the concept in figure 2. A photo of the experimental setup of the new Jet-EC Turning system is shown in figure 3.

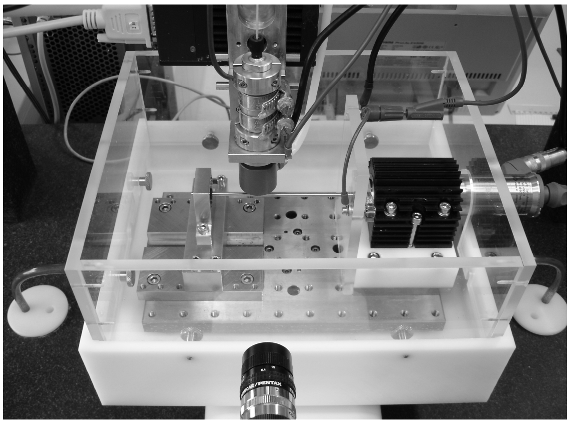


Figure 3: *Photo of the experimental setup of the Jet-EC Turning system*

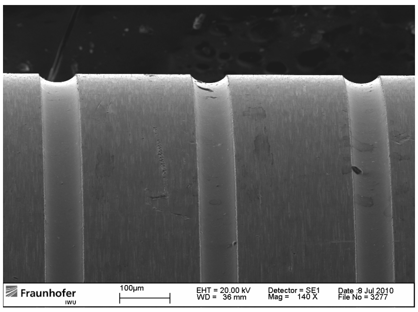
To generate the work piece rotation a high frequency motor spindle was applied with a speed range of 5000 - 60000 1/min. The work piece with a diameter of 3 mm was clamped by a chuck and a ball-bearing. By the use of carbon brush the connection of the work piece with the power supply was realized. Plastic components were applied to insulate the devices against electrochemical removal. Different experimental investigations were performed to characterize the influence of different process parameters on the machining results. In this study especially profile, cylindrical and contour turning processes were analyzed. Table 1 summarizes all parameters of the conducted experiments.

For a qualitative evaluation of the machining results figure 4 and 5 show SEM images of selected experiments. In figure 4 the results of the profile turning process are illustrated. Three cavities with a width of 70 µm and a depth of 20 µm were fabricated in an overall process time of 120 s. As shown in figure 4 right the cavities are generated with a high surface quality of the eroded areas.

The result of the cylindrical turning process is shown in figure 5 left. Over a length of 1000 µm an electrochemical removal of 60 µm in depth was achieved. A high surface quality of the machined areas is obvious.

Table 1: *Experimental parameters*

Symbol	***Parameter***	***Value***
	Electrolyte	*Sodium Nitrate*
	Work piece material	*Stainless steel shaft 1.4301 (Ø 3 mm)*
c	*Mass friction sodium nitrate*	*30 %*
d	*Nozzle inner diameter*	*50 µm (profile turning)* *100 µm (cylindrical and contour turning)*
dV/dt	*Pump delivery rate*	*2.5 ml/min (profile turning)* *5 ml/min (cylindrical and contour turning)*
a	*Working distance*	*100 µm*
U	*Electrical voltage*	*56 V*
n	*Rotation speed*	*5000 1/min*
v	*Nozzle motion speed in x-direction*	*10 µm/s (cylindrical turning)* *1000 µm/s - 20 µm/s (contour turning)*
z	*Number of nozzle movements*	*5 (cylindrical turning); 1 (contour turning)*
t	*Process time*	*40 s (profile turning)*



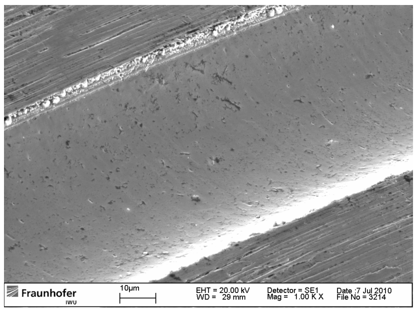


Figure 4: *SEM images of the results after profile turning process*

In figure 5 right the geometry of the work piece after a contour turning process is demonstrated. To realize the contour turning the motion speed of the nozzle was successive decreased from 1000 µm/s to 20 µm/s. Over a length of 2 mm a continuous removal up to 60 µm in depth was obtained. Also a high surface quality in the eroded areas is achieved.

For a quantitative analysis of the results an auto-focus system from the OPM-Messtechnik company was used to examine the surface quality of the Jet-EC Turning processes. It is a non-contacting measurement system for the detection of the surface roughness.

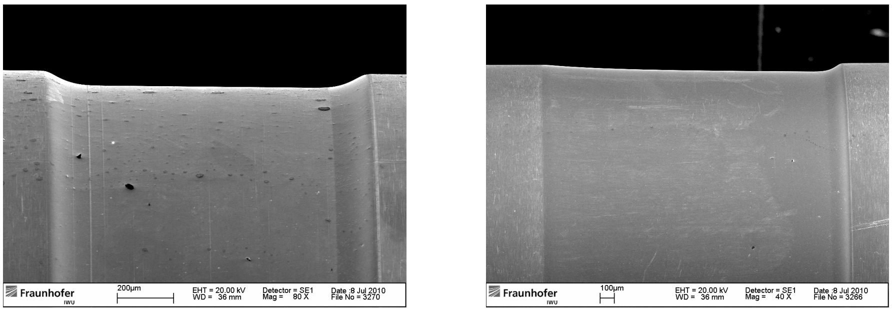


Figure 5: *SEM images of the results after cylindrical turning process (left) and after contour turning process (right)*

For all turning applications the roughness parameters are Rz ≈ 1 µm and Ra ≈ 0.25 µm, which is the typical roughness for the electrochemical machining with a closed electrolytic free jet [4].

4 Summary

In the present work a modified electrochemical procedure, the Jet-EC Turning, was specified for the machining of rotating work pieces. Also the development and realization of a new experimental setup was presented in this study. For a technological verification of the possibilities of micro electrochemical turning, different experiments were executed. Especially profile, cylindrical and contour turning processes were successfully performed with the new experimental setup. To extend the spectrum of micro turning with closed electrolytic free jet more experimental investigations are necessary to identify and systemize the influence of different process parameters on the machining results.

Literature

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