Transient Simulation of the Electrolyte Flow in a Closed Device for Precise Electrochemical Machining

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Abstract

The manufacturing technology electrochemical machining (ECM) finds numerous applications in industrial production. Especially for shaping and surface structuring of metals by controlled anodic dissolution the process is used. The advantages of ECM are mainly the high removal rates, the slight influence on the work piece material structure and the independence of material strength and hardness. Thus ECM is advantage compared to metal cutting manufacturing processes.

Precise electrochemical machining (PEM) is an innovative machining technology which results from further development of the electrochemical sinking. PEM works with pulsed low frequency direct current and oscillation of the tool electrode. It enables the manufacturing of tools and machine elements with high precision requirements and reproduction accuracy. [1, 2]
With PEM actually the manufacturing of structure sizes < 1 mm and flatness < 5 µm by front surface machining is possible. As part of the project 'Electrochemical machining of internal precision and micro-geometries with high aspect ratios by process-state-dependent electrolyte management' (ElAs) the aim is to develop a new combination of high pressure flush and a flexible electrode concept. Filigreed electrodes with structure elements smaller than 0.2 mm are targeted for the aimed manufacturing of big aspect ratios. Moreover inner micro structures are obstacle by them self for the needed electrolyte flush in the working cap. Due to this the manufacturing process has to be qualified to a non-flux of electrolyte at the dissolution process. Interaction between conduction and the geometry of the electrodes should be avoided. Therefore a closed process device has to be developed which is able to admit a defined pressure charge. By concerted modifications the oscillation inducted effect of compression should become accessible as input parameter for the process.

Experimental research of model geometries regarding to the electrode shape, the inducted compression, the precision, the surface and the current efficiency are content of the project. Multiphysics simulations are applied to characterise the modified process.

For the simulation of the electrolyte flow in the closed device COMSOL Multiphysics® is used. To get use of the simulation software a suitable model geometry has to be deducted and initial values must be defined. Sketches of cross sections of the closed device and the developed model geometry are given in Figure 1.

The closed device has a cylindrical shape with connections for the electrolyte supply. Thus the device isn't rotationally symmetric. The electrolyte flow results from interaction of the transverse flow and the tool electrode oscillation. One challenge is to develop a model which fits the geometric requirements of the closed device and even the requirements for simulation. The numerical simulations of high turbulent flows are really sophisticated and a lot of computing power is needed [3]. Therefore the simulation is designed in a 2-dimensional environment and the geometric specifications were adjusted accordingly to comply with these claims.

By soling a transient model of turbulent flow the field of velocity in the closed device can be shown. A surface plot of the magnitude velocity of time step t = 0.01 s is given by Figure 2.

It can be recognized that the field of velocity in the closed device is highly turbulent with many random vortexes. This is due to the interaction of oscillating velocity at the upper edge of the model and the transverse flux in the closed device.

Reference

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[3] S. Lecheler, Numerische Strömungsberechnung, II. Wiesbaden: Vieweg+Teubner Verlag, 2011.

Figures used in the abstract

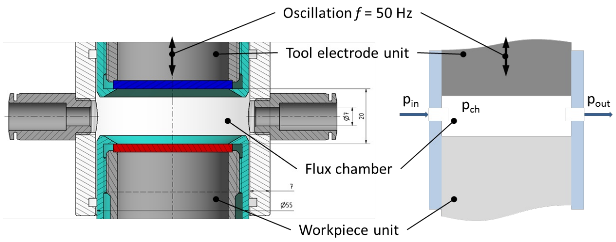

Figure 1: Schematic cross sections of the closed device (left) and the developed model geometry (right), pin is pressure at inlet, pch is pressure in chamber, pout is pressure at outlet

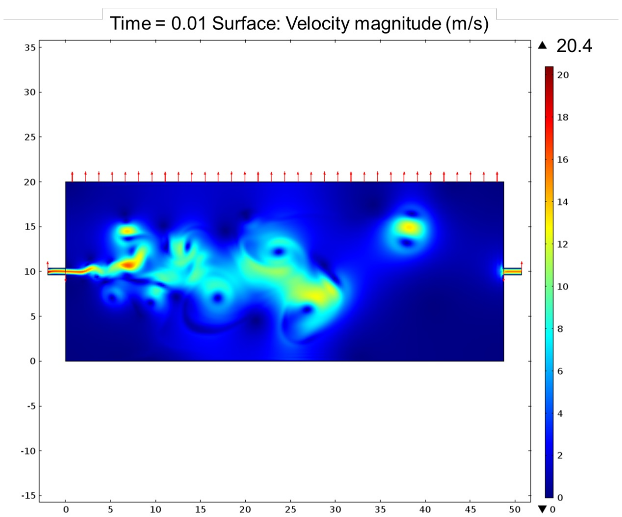

Figure 2: Surface plot of the magnitude velocity at time step t = 0.01 s