2D Axisymmetric Simulation of Pulsed Electrochemical Machining (PECM) of Internal Precision Geometries

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Abstract

In several fields of mechanical engineering internal precision geometries are applied. For example for shaft-hub connections various shapes of internal geometries are needed, like involute splines or feather key grooves. For this application requirements like high shape accuracy, sufficient stability, high wear resistance or an increase of life time have to be fulfilled. However, there is also a demand on quick and precise manufacturing processes that are flexibly in machining various internal geometries. Electrochemical machining (ECM) is a process which meets these requirements. This process allows surface structuring and shaping of metal components with high shape accuracy independently of the materials strength and hardness [1].

For the manufacturing of internal precision geometriesm, pulsed electrochemical machining (PECM) was chosen. This process is a further development of EC-lowering and is characterized by a moving cathode and pulsed direct current [2, 3]. The peculiarity of machining internal geometries is the shaping of the workpiece perpendicular to the feed direction. Therefore, the peripheral working distance has to be determined, which is dependent on various process parameters. This study presents investigations on a developed process design by the help of multiphysics simulations. Figure 1 shows the process design. The design consists of pre-drilled cylindrical workpieces for reducing the required material removal and thus the required electric charge. With the help of a clamping element the workpiece is fixed in location and orientation. The cathode consists of a lateral electrically insulated cylinder at which a replaceable disc with the functional surface is mounted by a further clamping element. In the machining process, the working gap is constantly flushed with electrolyte and the cathode is sunk into the workpiece with a continuous feed to produce the aspired internal precision geometry.

Based on this design concept, a multiphysical simulation model was developed which can be used for achieving a more efficient process design. Therefore, a 2D axisymmetric transient model was created. The considered physical phenomena are fluid dynamics, thermodynamics, electrodynamics, the formation of hydrogen gas as well as geometry deformation. The model allows a detailed description of PECM of internal precision geometries. One selected result is shown in a sectional view in Figure 2. Here, the pseudo-

color corresponds to the field of the effective electrical conductivity of the electrolyte. For example, Joule heating along the workpiece surface causes an increase of the electrical conductivity of the electrolyte, while the formation of hydrogen along the anode surface reduces the effective electrical conductivity. This simulated distribution of the electrical conductivity has a major influence on the local current density within the working gap and thus on the resulting geometry of the workpiece. The resulting geometry is calculated up to a machining time of 250 s applying the developed model. So, the use of COMSOL Multiphysics® software can predict the material removal behavior and helps to perform further development and optimization in the process design.

Reference

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Figures used in the abstract

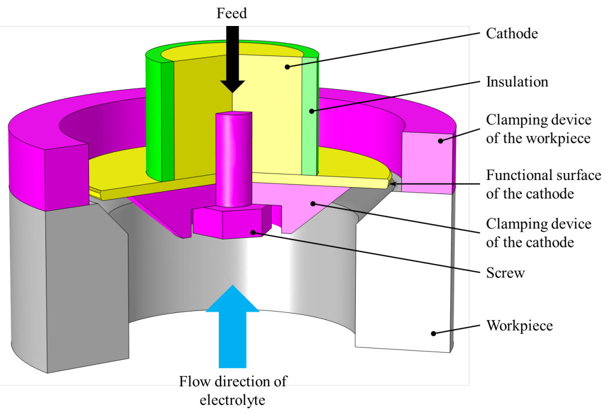

Figure 1: Design concept for machining internal precision geometries with Electrochemical Machining.

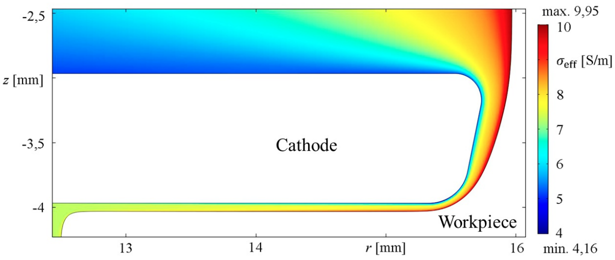

Figure 2: 2D sectional view of the effective electrical conductivity at time step t1 = 250 s.