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Study on the dynamic generation of the jet shape in Jet Electrochemical Machining

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ABSTRACT

Jet Electrochemical Machining (Jet-ECM) is a technology for fast creating microstructures into metallic parts without any thermal or mechanical impact and independent from the material's hardness. The processed surface is very smooth and no tool wear occurs. The Jet-ECM process depends strongly on the shape of the jet which is hardly predictable. In a previous study Hackert (2010) built a numerical model with COMSOL Multiphysics based on a predefined jet shape. In the present study a new model was created integrating fluid dynamics using the level set method for two-phase flow. According to the Jet-ECM process the simulation was divided into two steps. In the first step the jet is formed. In the second step the anodic dissolution is simulated by deforming the geometry. The dynamic behavior of the electrolyte jet could be simulated during the dissolution process. So effects became visible which affect the machining results. The results of the present study lead to a better understanding of electrochemical machining via electrolytic free jet. Especially a secondary electric contacting of the nozzle by electrolyte reflected from the work piece could be proven.

1. Introduction

Jet Electrochemical Machining is a manufacturing technology which is based upon anodic dissolution. Hackert-Oschätzchen et al. (2012) showed that the manufacturing method enables a fast production of complex micro geometries. Defined volumes of material can be removed from metallic work pieces by concentrating an electric direct current in an electrolyte jet, ejected from a small nozzle. Working gaps down to 25% of the nozzle diameter between work piece and nozzle can be used. The removal depends on the local current density which, as Schubert et al. (2011) found, amounts up to 2100 A/cm^2. This high current density is locally restricted by the shape of the jet. Hackert-Oschätzchen et al. (2013) revealed that Jet-ECM is qualified to machine carbide metals. Hommel et al. (2013) and Hackert et al. (2010b) showed the technology's flexibility applying inverse Jet-ECM as well as Jet-EC Turning. The major benefits of Jet Electrochemical Machining are the high localization of the machined area and the high achievable surface quality. During machining no tool wear occurs.

One important parameter of the process which strongly influences the results is the shape of the jet. However, it is hardly predictable. Yoneda and Kuneida (1995) showed an axially symmetric stationary model of Jet-ECM for a plane surface at machining time zero, which has been proven by Natsu et al. (2006). Based on this Hackert (2010) created a numerical model with COMSOL Multiphysics to describe the process of material dissolution. The jet shape was predefined as a domain with a flexible mesh. The simulated dissolution results progressively differ from experimental results with increasing processing time. This difference is based on the fact that this model does not consider dynamic interaction of the fluids with the calculated geometry. Hackert et al. (2010a) made an improvement of the simulation by using a dynamic jet shape.

In the present study the jet shape is simulated considering fluid dynamics to gain a more realistic model. The dynamic generation of the jet shape could be investigated and a secondary contact between work piece and nozzle by reflected electrolyte could be shown.

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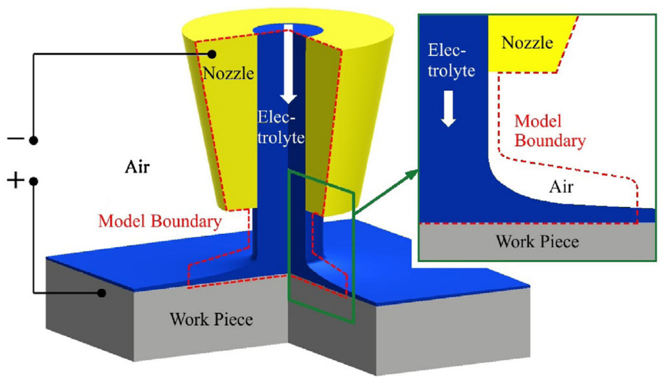


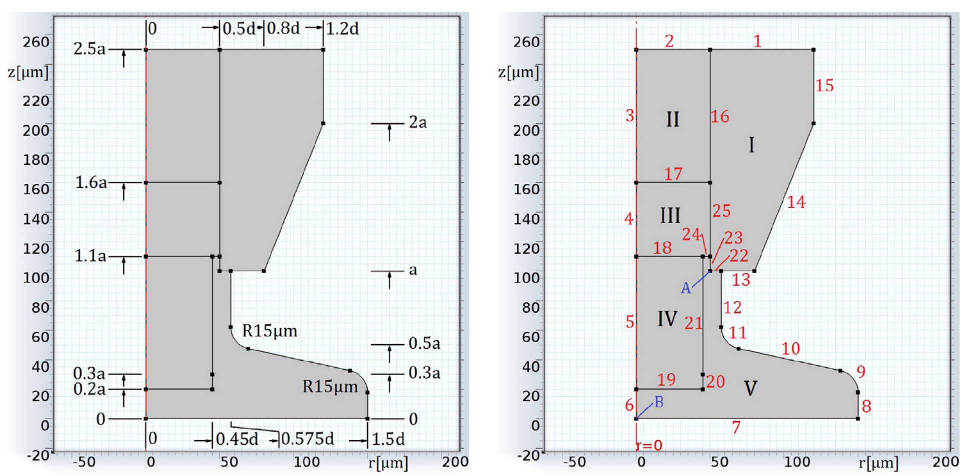
Fig. 1. Scheme of the developed model.

2. Model description

The developed model consists of couplings of the physical phenomena electrodynamics, fluid dynamics and deformation of the geometry. Beginning with the initial geometry given by the used nozzle fluid dynamics is solved and the jet shape is calculated. Electrodynamics is calculated based on the simulated jet shape. The material removal is implemented by deforming the geometry using Faraday's law and the calculated electric current density. The deformed geometry interacts with the jet shape and thus with electrodynamics. These three couplings are determined in every time step.

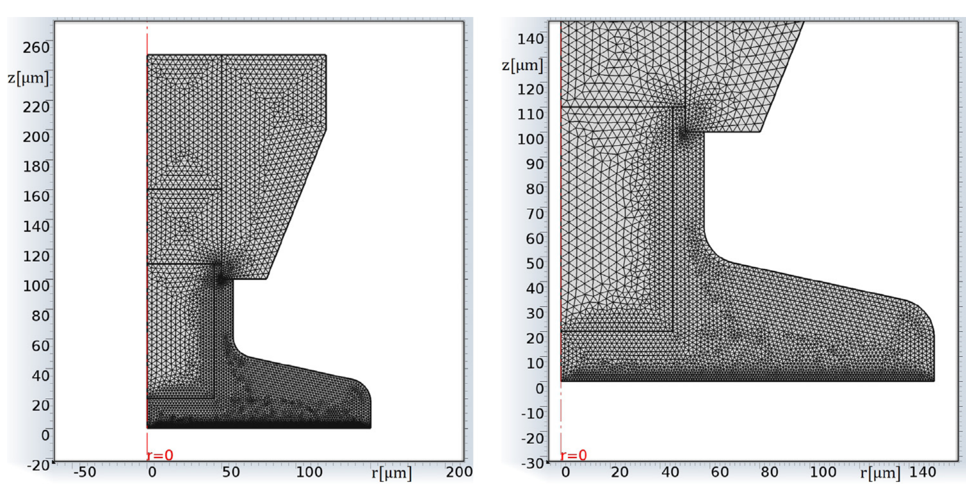
Fig. 1 shows a scheme of the developed model.

The model encompasses a small zone in adjacencies of the free jet. It is assumed that electrolyte exiting this zone through the model boundary is immediately removed by the airflow. This entails that the model neglects a possible secondary contacting of reflected electrolyte and the nozzle. Furthermore the flow of the electrolyte is assumed to be symmetric and stable. Therefore a 2D axially symmetric model is used. Moreover the model is built up parametrically to be able to modify the geometry easily.



(a) Dimensions with parameters a and d (b) Definition of domains, boundaries and points

Fig. 2. Parametrical model geometry with $a = d = 100\,\mu\text{m}$.



(a) Complete mesh (b) Detail

Fig. 3. Generated mesh.