2D Axisymmetric Simulation of the Electrochemical Finishing of Micro Bores by Inverse Jet Electrochemical Machining

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Finishing of Micro Bores

- For fuel injection systems a defined edge shape of micro bores is needed to adjust the combustion properties
- Inverse Jet-ECM as procedure to realize the edge shape
- Development of a tool system for machining fuel injectors based on the results of the simulations (**Fig. 1**)
- Commercial dispense tips applied as model geometry for experimental investigations and simulations (**Fig. 2** and **Fig. 6**)

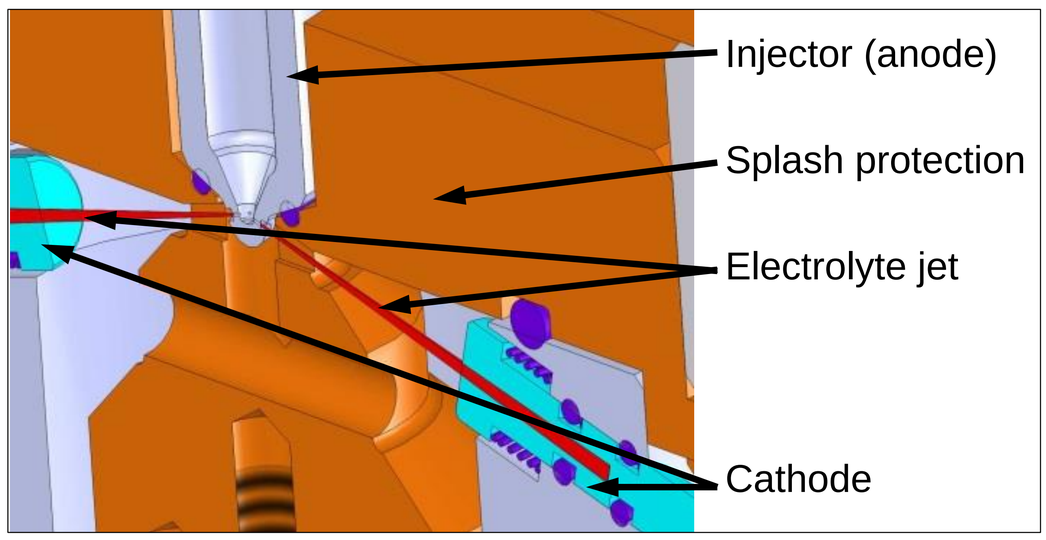

Figure 1: Scheme of the tool system for electrochemical finishing of fuel injectors by inverse Jet-ECM [1]

Transient Model of Inverse Jet-ECM

- Implementation of the basic experimental arrangement into an axisymmetric model (**Fig. 2** and **Fig. 3**)
- Electrodynamics (**Tab. 1**), prediction of removed material and resulting geometry by applying Faraday's Law on boundaries 5 and 6 (**Fig. 3**)

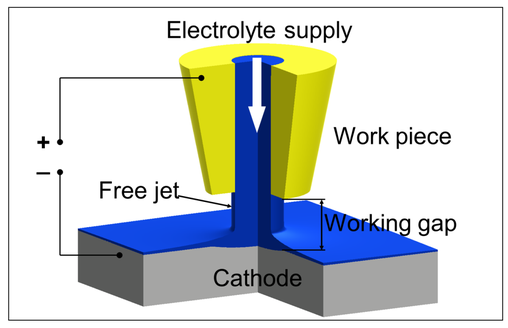

Figure 2: Principle of Inverse Jet Electrochemical Machining [2]

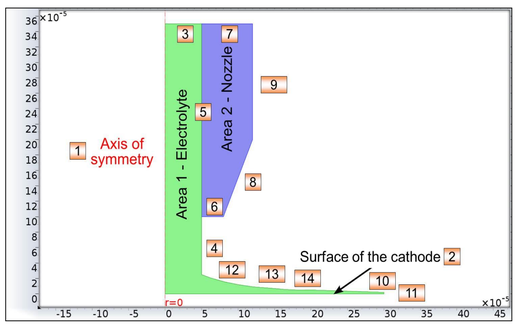

Figure 3: Axisymmetric ECM model with numbers of boundaries

$$\vec{v}_n = \eta \cdot \frac{M}{z_A \cdot \rho \cdot F} \cdot \vec{J}_n$$

v_n = normal velocity of work piece surface
η = current efficiency (100 %)
M = molar mass (54.94 g/mol)
z_A = valency (2.4)
ρ = mass density (7.77 g/cm³)
F = Faraday constant ($9.65 \cdot 10^4$ C/mol)
J_n = normal current density

Boundary	Definition
1	Axis of symmetry
2	$U = 0$ V
3	$\vec{n} \cdot \vec{j} = 0$
4	$\vec{n} \cdot \vec{j} = 0$
5	Continuity
6	$\vec{n} \cdot \vec{j} = 0$
7	$U = 34$ V
8-14	$\vec{n} \cdot \vec{j} = 0$

Table 1: Boundary conditions (**Fig. 3**)

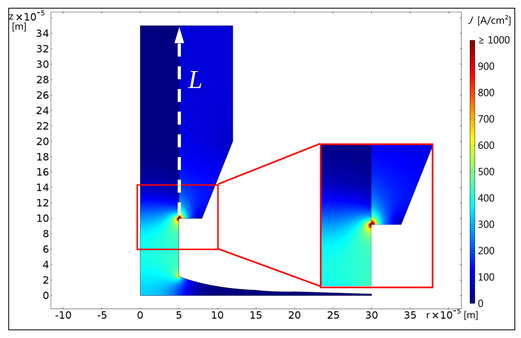

Figure 4: Surface plot of electric current density distribution [2]

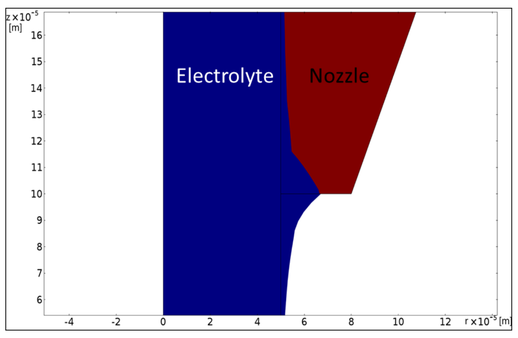

Figure 5: Simulation result of the transient electrochemical erosion at t = 0.1 s

Results

- Existence of a current density maximum at the edge of the micro bore (**Fig. 4** and **8**)
- Highly localized material dissolution according to the simulated current density distribution (**Fig. 5**)
- Experimental removal geometry (**Fig. 7**) shows very good coincidence to the simulated removal geometry (**Fig. 5**)
- Successful adjustment of flow rate with inverse Jet-ECM (**Fig. 9**) in a sequential machining process

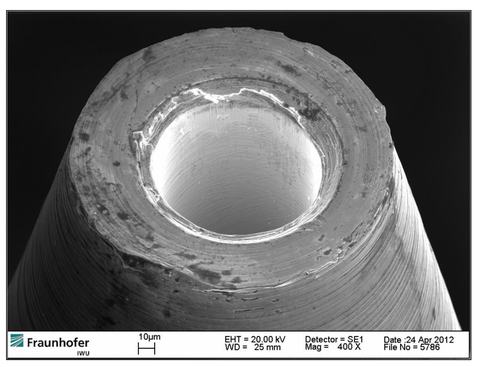

Figure 6: SEM image of an unmachined micro nozzle [2]

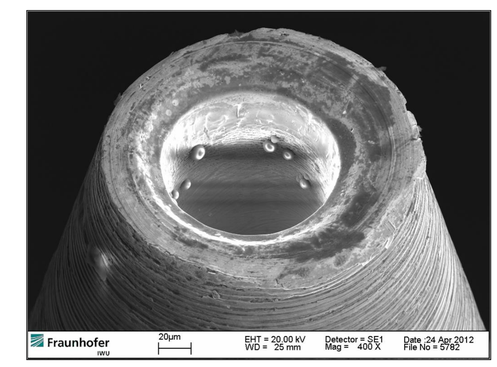

Figure 7: SEM image of a micro nozzle after 0.1 s of inverse Jet-ECM [2]

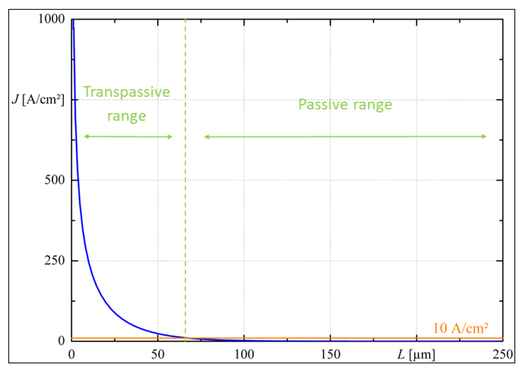

Figure 8: Electric current density as function of the arc length along bore interior wall [2]

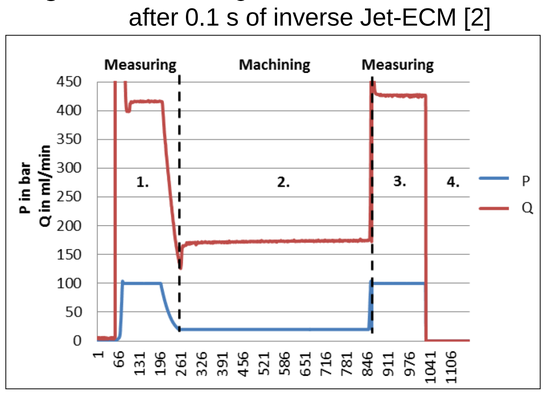

Figure 9: Diagram of flow rate and working pressure within one processing sequence [1]

Acknowledgements

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References:

[1] B. Hommel, F. Jähn, M. Scharrnbeck, R. Garn, A. Lenk, M. Hackert-Oschätzchen, A. Schubert: Edge Rounding of Micro Bores by Inverse Jet Electrochemical Machining, Pro-ceedings of the 9th International Symposium on Electrochemical Machining Technology, accepted for publication

[2] M. Hackert-Oschätzchen, A. Martin, G. Meichsner, M. Kowalick, H. Zeidler, A. Schubert: Inverse Jet Electrochemical Ma-chining for Functional Edge Shaping of Mi-cro Bores, Procedia CIRP 6 (2013) 379-384, DOI: 10.1016/j.procir.2013.03.060.

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