Analysis of an Electrochemical Machining Process for Particle Reinforced Aluminium-Matrix Composites

M. Hackert-Oschätzchen[1], N. Lehnert[1], M. Kowalick[1], C. Scherf[2], D. Kuhn[1], A. Martin[1], A. Schubert[1,2]

Electrochemical Machining of Aluminium Matrix Composites (AMC)

- Particle reinforced metals are difficult to machine due to different local conditions
- AMCs consist of aluminium alloy EN AW 2017 as matrix material, reinforced by SiC particles
- Investigation of Jet Electrochemical Machining (Jet- ECM) as alternative technology for finishing machining → targeted uncovering of SiC particles (**Fig. 1**)
- Dissolution simulation with a fully coupled model using interface primary current distribution in the field of electro-chemistry (**Fig. 2**)

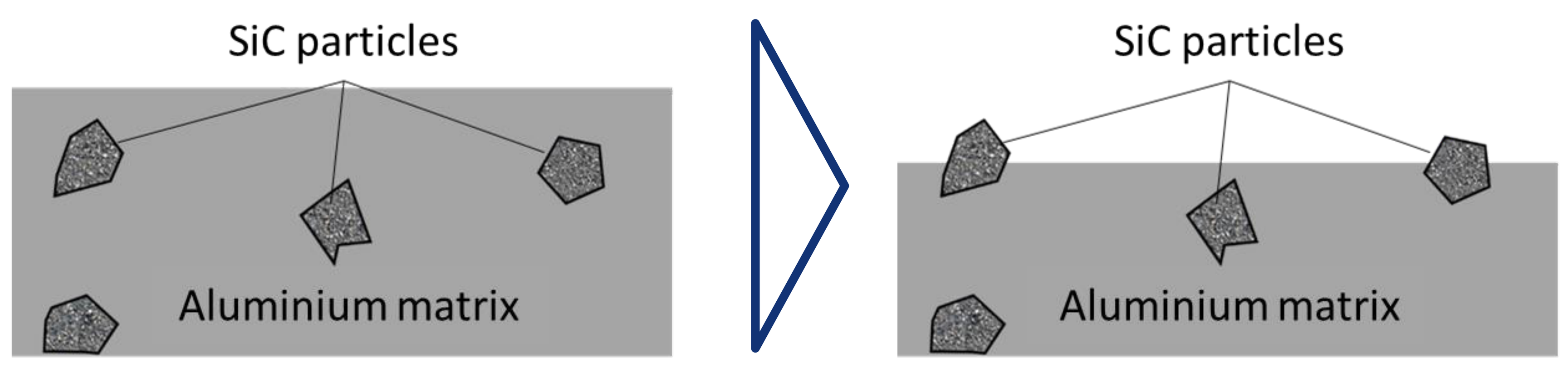

Figure 1. Scheme of the AMCs before and after the EC-processing for targeted uncovering of the reinforcement SiC particles

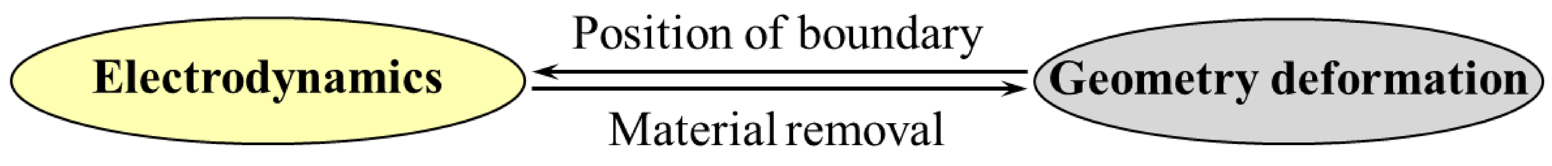

Figure 2. Considered couplings within the interface of primary current distribution in the field of electro-chemistry

Results

- Performing removal simulation up to electro-chemical machining time of t = 0.039 s (**Fig. 3**)
- Current density minimum of 20 A/cm² at particle tip
- Current density maximum of 69 A/cm² at the transition from particle to matrix
- Local current density maximum next to SiC particle leads to increased material removal in this area during machining process (**Fig. 4**)

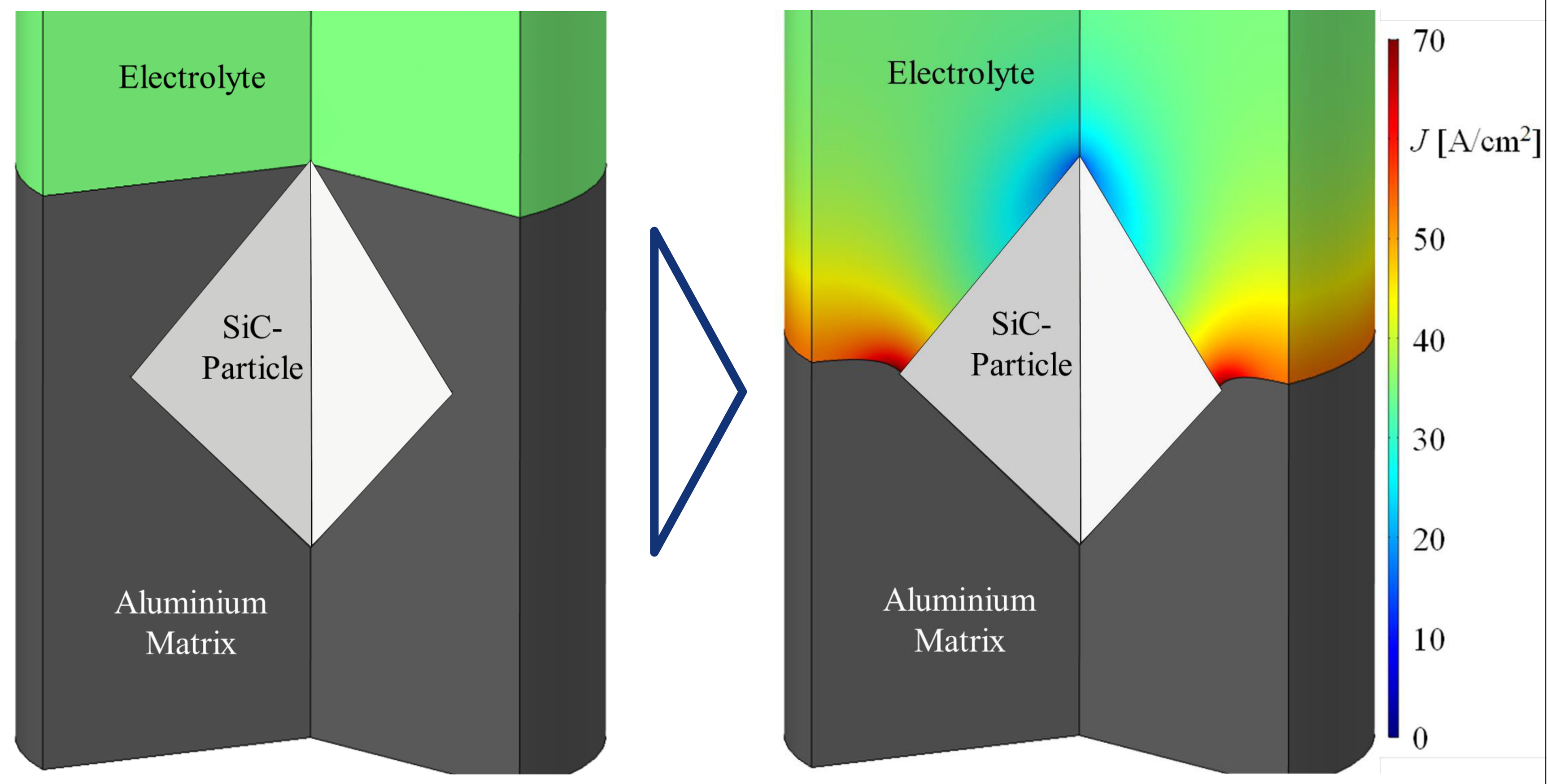

Figure 3. Workpiece shape and false color rendering of the electric current density at t = 0 s and at t = 0.039 s

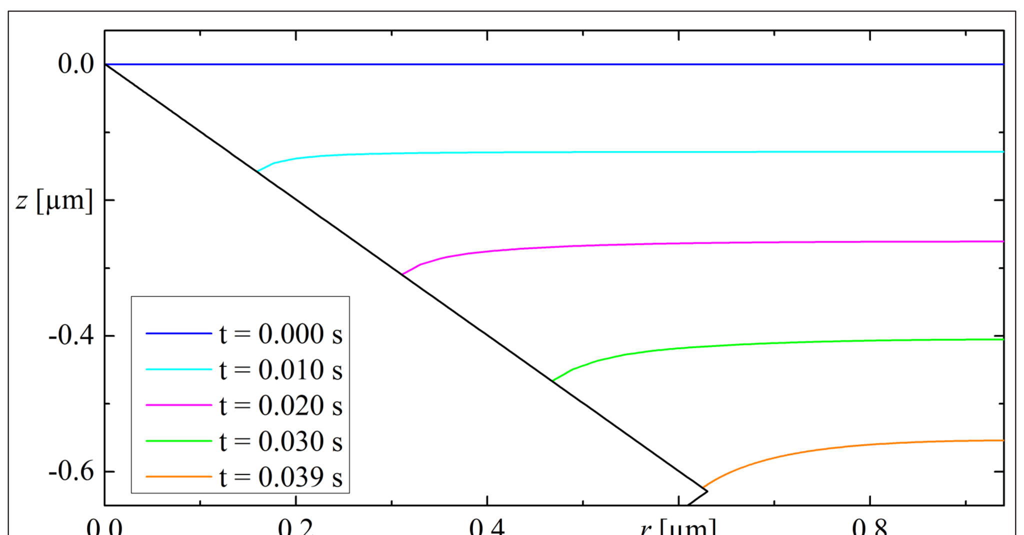

Figure 4. Resulting shape of the workpiece surface at different timesteps

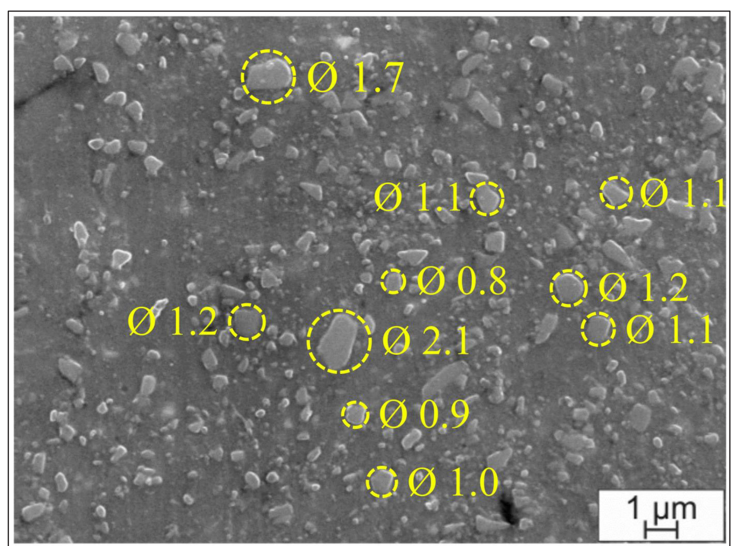

Figure 5. SEM-image of an AMC surface for ascertaining the averaged particle size

Model creation

- Derivation a 2-D axisymmetric model from the cylindrical geometry of Jet-ECM an AMC unit cell (**Fig. 6**)
- Deriving particle size from SEM-image (**Fig. 5**)
  → Averaged size of 1.0 µm
- Deriving double cone while maintaining the particle volume

Allocation of defined settings		
Domain	**Material**	**Defined setting**
I	Electrolyte	$r_{El} = 0.94$ µm $h_{El} = 100$ µm $\sigma = 70$ mS/cm
II	Aluminium alloy EN AW 2017	$r_{AL} = 0.94$ µm $h_{AL} = 1.88$ µm $\rho = 2.8$ g/cm³ $M = 28.77$ g/mol
III	SiC	$r_{DC} \approx 0.63$ µm $h_{DC} \approx 1.26$ µm

- Prediction of removed material and resulting geometry by applying Faraday's Law (z_A = 2.7):

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

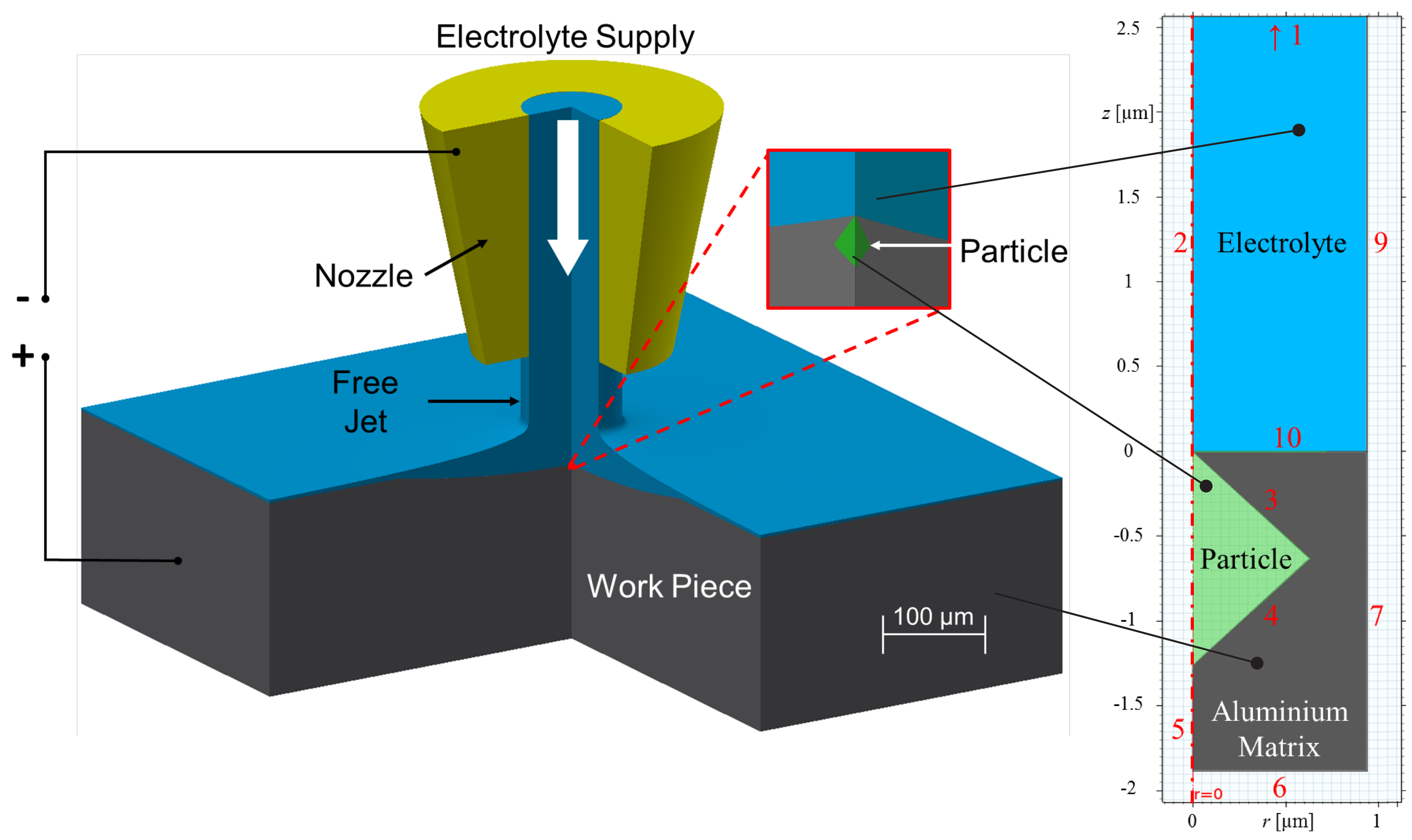

Figure 6. Scheme of jet electrochemical machining of AMC and derived 2-D axisymmetric model geometry for Jet-ECM of particle reinforced AMC

Acknowledgements

The authors acknowledge the DFG (German Research Foundation) for supporting this work carried out within the framework of project SFB 692 HALS.

Deutsche Forschungsgemeinschaft

SFB 692 HALS

TECHNISCHE UNIVERSITÄT CHEMNITZ

1
Technische Universität Chemnitz
Professorship Micromanufacturing Technology
Faculty of Mechanical Engineering
Reichenhainer Straße 70
09126 Chemnitz
Germany

Prof. Dr.-Ing. Andreas Schubert
Tel.: +49 (0) 371 531-34580
Fax: +49 (0) 371 531-23549
mft@tu-chemnitz.de

Fraunhofer IWU

2
Fraunhofer IWU
Institute for Machine Tools and Forming Technology
Reichenhainer Straße 88
09126 Chemnitz
Germany