Modeling of the Material/Electrolyte Interface and the Electrical Current Generated During the Pulse Electrochemical Machining of Grey Cast Iron

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Initiative PRECISE

PECM Process:

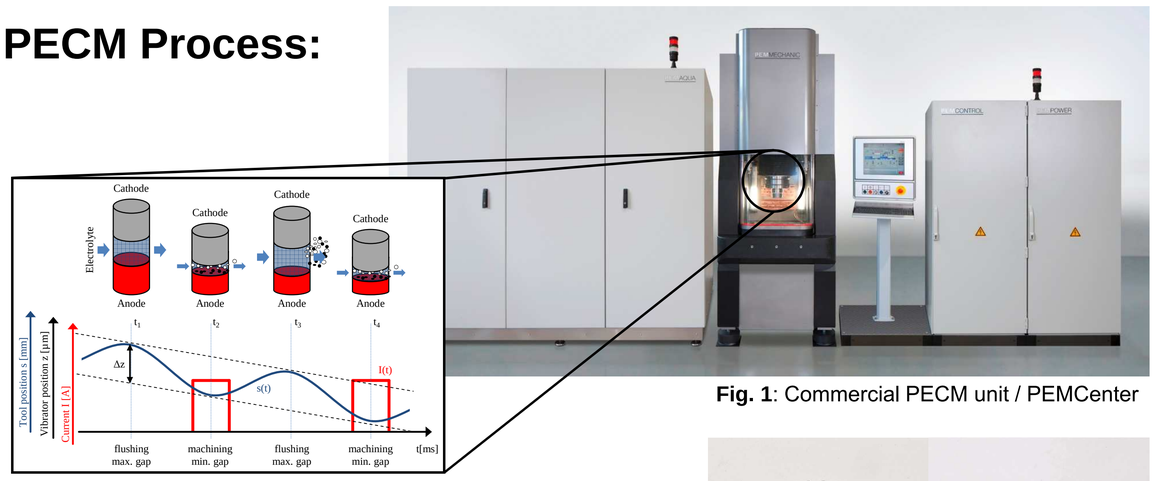

Fig. 1: Commercial PECM unit / PEMCenter

- Anodic dissolution of metallic workpieces applying pulsed current and oscillating tool electrode [1-2]
- Advantages of PECM:
  - No influence of material hardness or ductility
  - No thermal or mechanical impact on the workpiece
  - No tool wear, no burring
  - High surface quality, high reproducibility

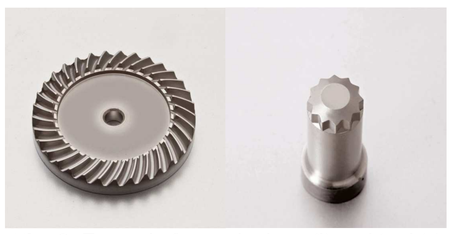

Fig. 2: Example for work piece (l) and tool (r)

Experimental

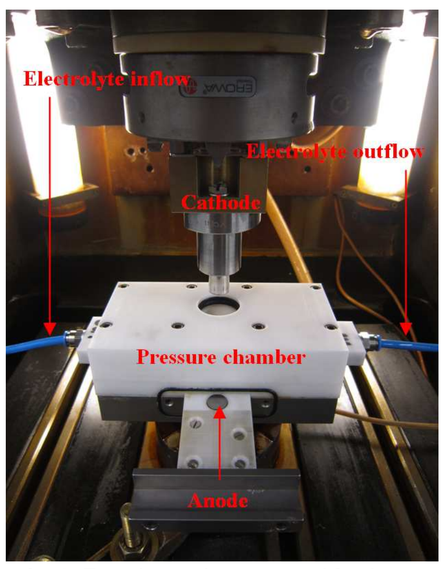

Fig. 3: Experimental set-up used for the model validation

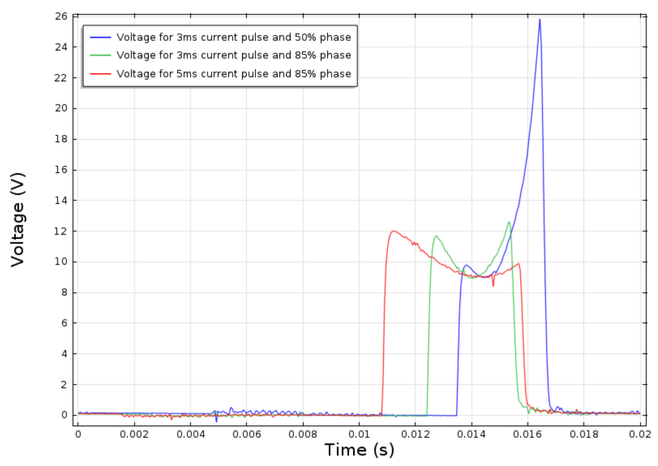

Fig. 4: Pulsed voltage signals recorded during the experimental investigations and used as input in the simulations

	Name	Value
v_f	Cathode feed rate	0.1mm/s
Δz	Vibration amplitude	373µm
T	Vibration period	20ms
t_{on}	Pulse on-time	3ms and 5ms
χ	Phase	50 % and 85 %
U	Voltage amplitude	9V

Tab. 1: Simulated process conditions

Modeling:

Simulation of the experimental conditions using an axisymmetric model

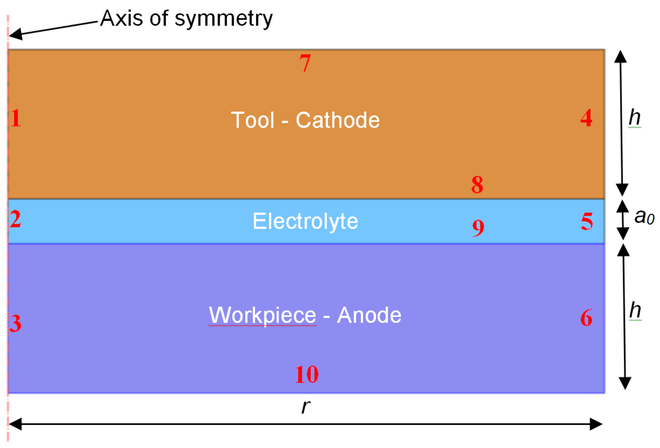

Fig. 5: Axisymmetric PECM model

Boundary	Condition
1 - 3	Axial symmetry
4 - 6	Insulation
7	Ground
8	Continuity
9	Terminal
10	Insulation

Tab. 2: Boundary conditions for the boundaries numbered in Fig. 5

	Name	Value
h	*Sample height*	5.5mm
a_0	*Initial interelectrode gap*	30µm
r	*Sample radius*	6mm

Tab. 3: Geometric model dimensions

Implementation of the material/electrolyte interface properties using an equivalent circuit

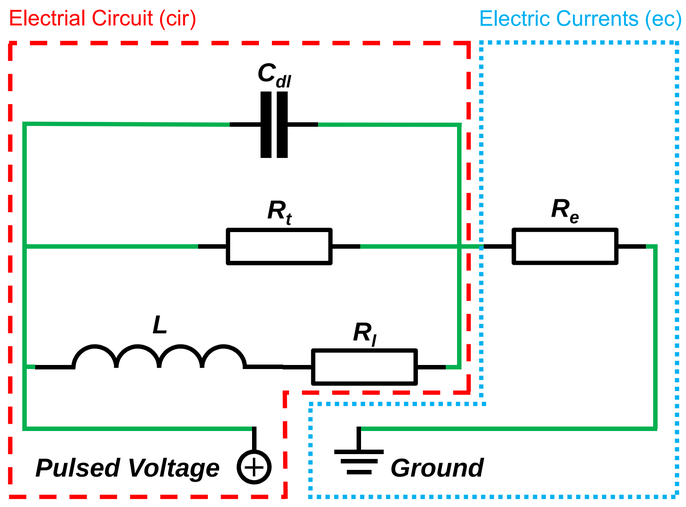

Fig. 6: Equivalent circuit developed by Electrochemical Impedance Spectroscopy investigations

	Name	Value
Q_{dl}	Pseudo-capacity	$2.6 \cdot 10^{-4}$F/s $^{\alpha-1}$
R_t	Charge-transfer resistance	2.2Ω
R_l	Relaxation resistance	7.6Ω
L	Relaxation inductance	0.14
α	Damping exponent	0.8
R_e	Electrolyte resistance	From simulation

Tab. 4: Material/Electrolyte properties

Imperfect capacitor behavior:

$$C_{dl} = Q_{dl} \cdot (j \cdot \omega)^{\alpha-1}$$

Material removal calculated from Faradays Law :

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

- v_n: normal velocity of workpiece surface
- J_n: normal current density

	Name	Value
η	Current efficiency	100%
M	Molar mass	55.85g/mol
z	Valence	2
ρ	Mass density	7,30kg/m³
F	Faraday constant	$9.6 \cdot 10^4$C/mol

Tab. 5: Material properties

Results

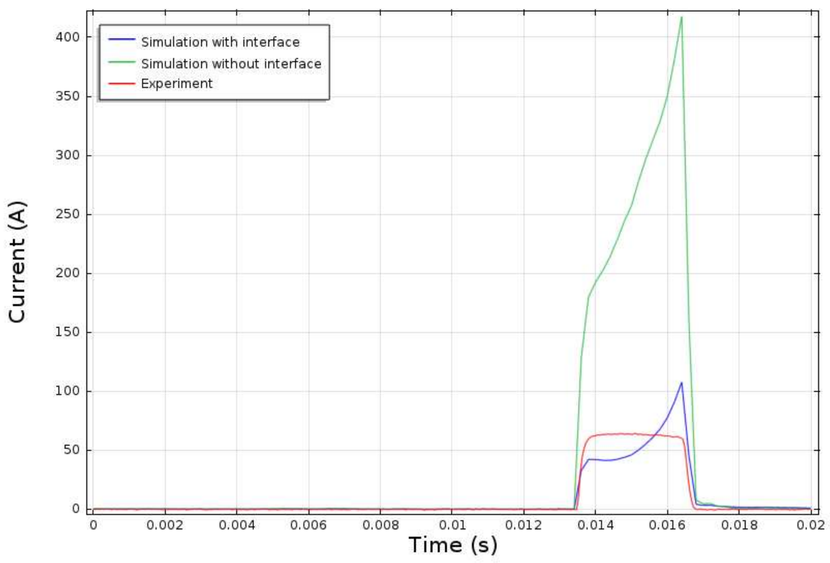

Fig. 7: Simulation of the current generated with and without interface compared to experimental results by a pulse on-time of 3ms and a phase of 85%

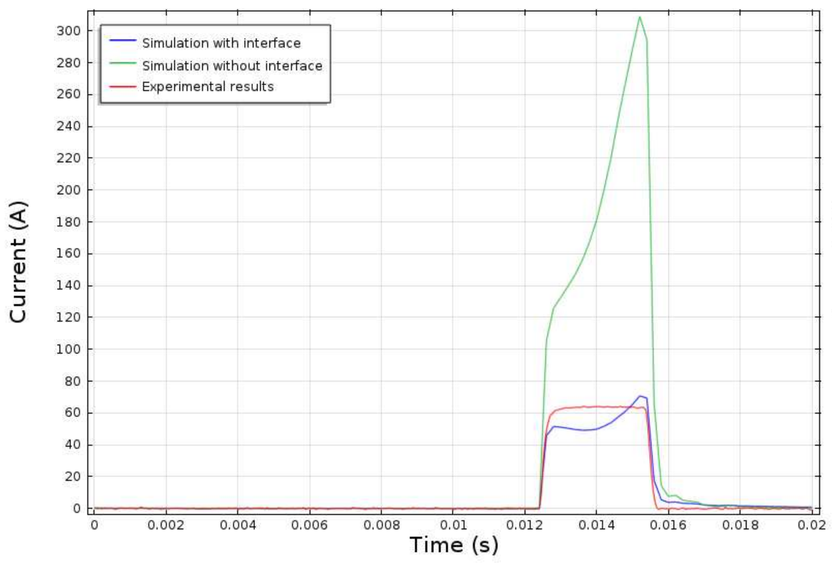

Fig. 8: Simulation of the current generated with and without interface compared to experimental results by a pulse on-time of 3ms and a phase of 50%

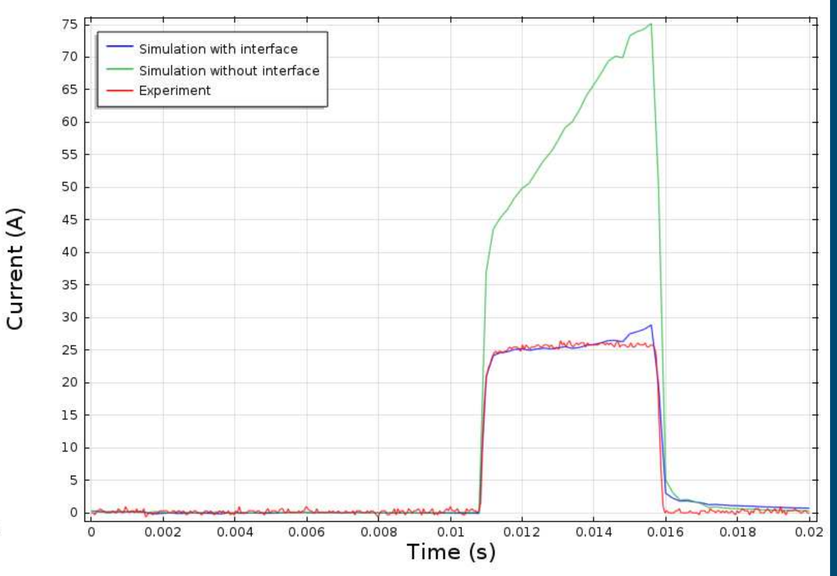

Fig. 9: Simulation of the current generated with and without interface compared to experimental results by a pulse on-time of 5ms and a phase of 85%

Summary

Implementation of the material/electrolyte interface significantly improves the simulation quality for predicting the current evolution during the PECM process

Difference between simulations with and without interface increase with the diminution of the pulse time

References

[1] *Procedia CIRP 6*, 362-367, (2013)

[2] *Ann. CIRP 48/2*, 567-579, (1999)

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