Copper Electrochemical Polishing Optimisation

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Introduction

A new electrochemical polishing (EP) facility will be built at CERN to process a wide range of SR accelerating cavities, and this in the framework of the Future Circular Collider study.

COMSOL Multiphysics® was used to assess the main working variables like potential, current density, electrolyte fluid dynamics to guarantee, not only, that polishing conditions were achieved inside the copper structure, but also that they were as even as possible; consequently the optimal cathode geometry was identified as well as services specifications.

Computational method, secondary current distribution module

Objective Simulation of the current density distribution across the cavity surface.

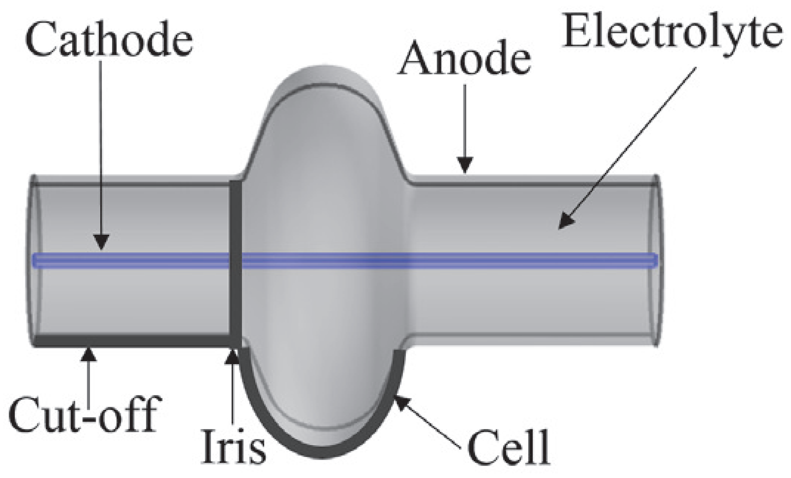


Figure 1. Model geometry (400 MHz cavity + cathode).

Electron transfer reactions

Anode (cavity surface) $Cu \rightarrow Cu^{2+} + 2e^-$

$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

Cathode $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

Model construction

- Physics interface: Secondary current distribution (SCD).
- Type of study: Stationary.
- Boundary conditions:

  Cathode surface: $\phi_{s,\,ext.} = 0$ V

  Anode surface: $\phi_{s,\,ext.}$ = Ecell
- Electrodes kinetics defined using polarisation curves.

Computational method, fluid dynamics module

Objective Simulation of the electrolyte velocity distribution in the 400 MHz cavity.

Model construction

- Physics interface: Laminar Flow combined with wall distance interface.
- Type of study: Stationary
- Boundary conditions:

  Inlet: Set with a laminar inflow of 50 lpm.

  Outlet: Set with pressure.

  Cavity walls: Non slip condition.

  Gravity: Included with Volume Force node.

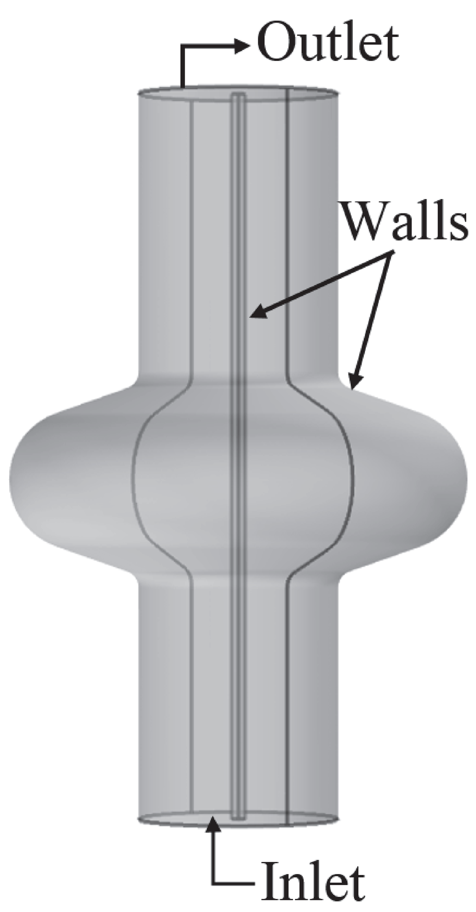
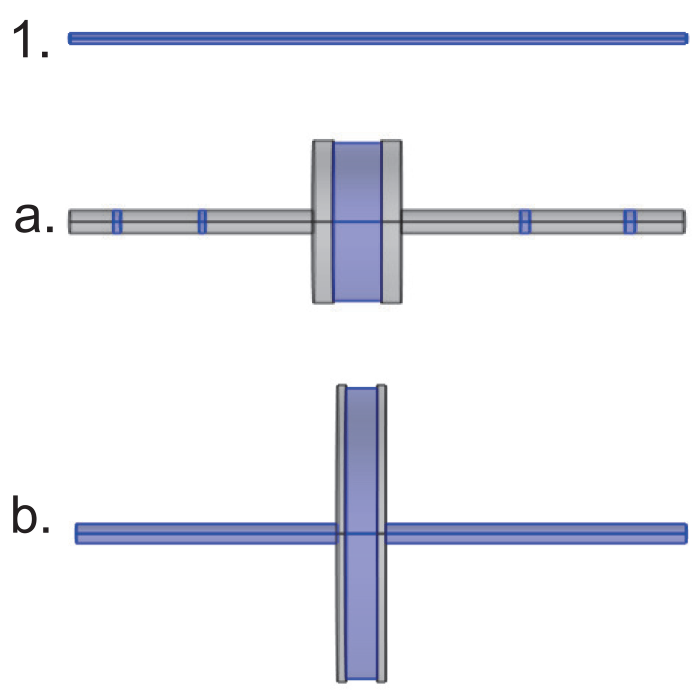


Figure 2. Drawing of the model used.

Results

Output from the Electrochemical simulations



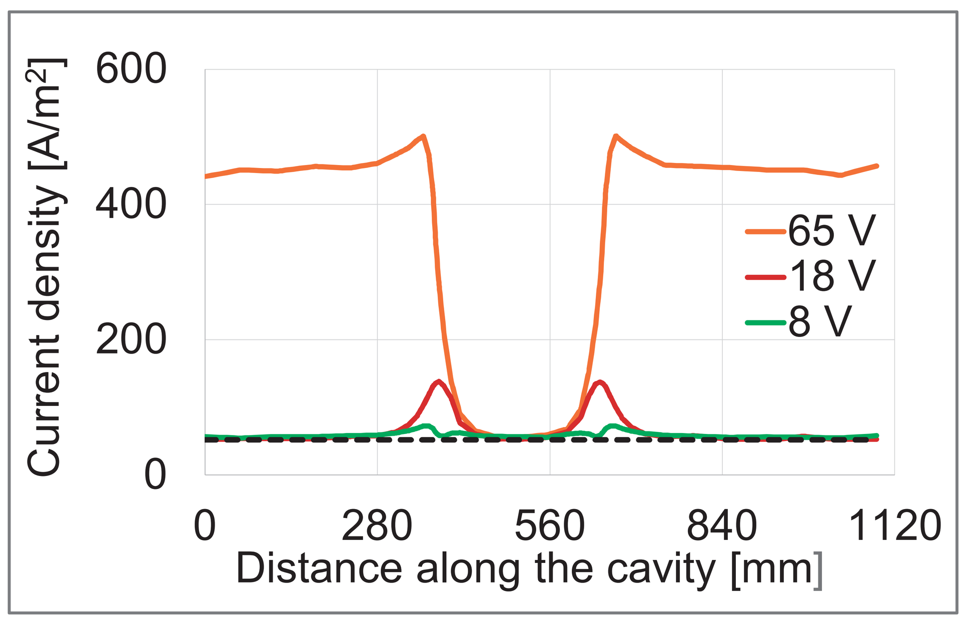
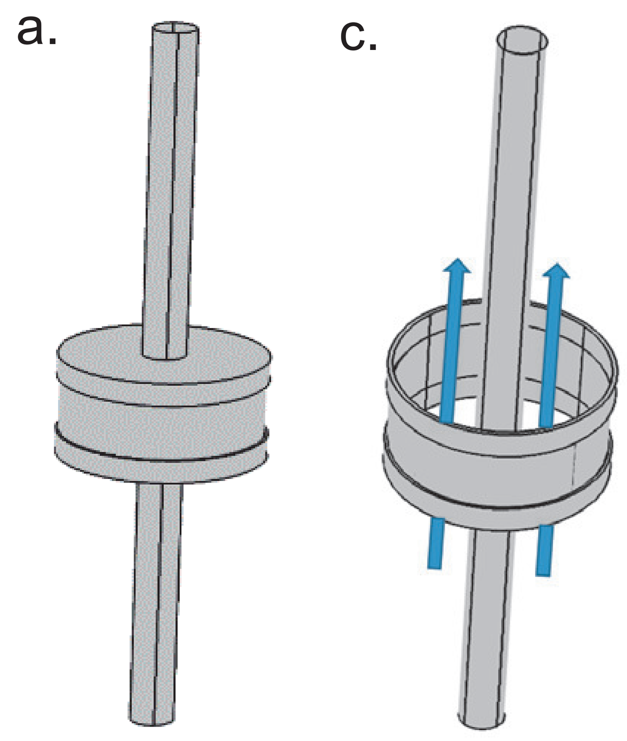


Figure 3. Starting cathode(1), cathode 'a', cathode 'b', min current density to EP.

Output from the Fluid dynamics simulations



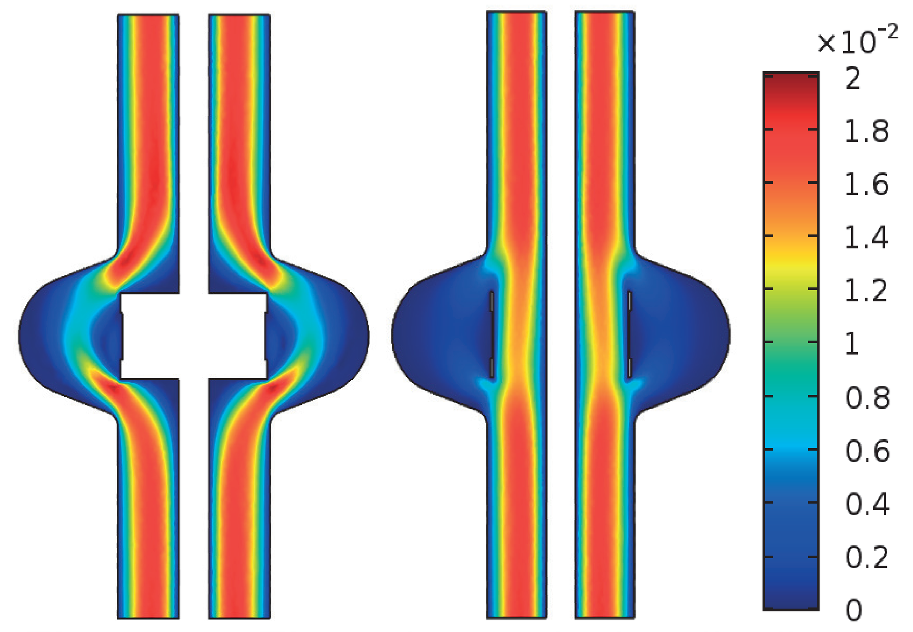


Figure 4. Electrolyte velocity distribution [m/s] with cathodes 'a' and 'c' respectively.

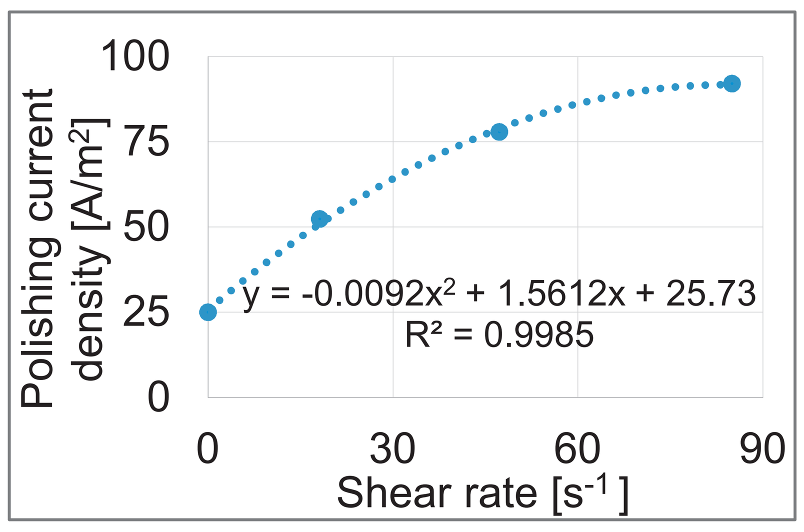


Figure 5. Correlation polishing current density and shear rate.

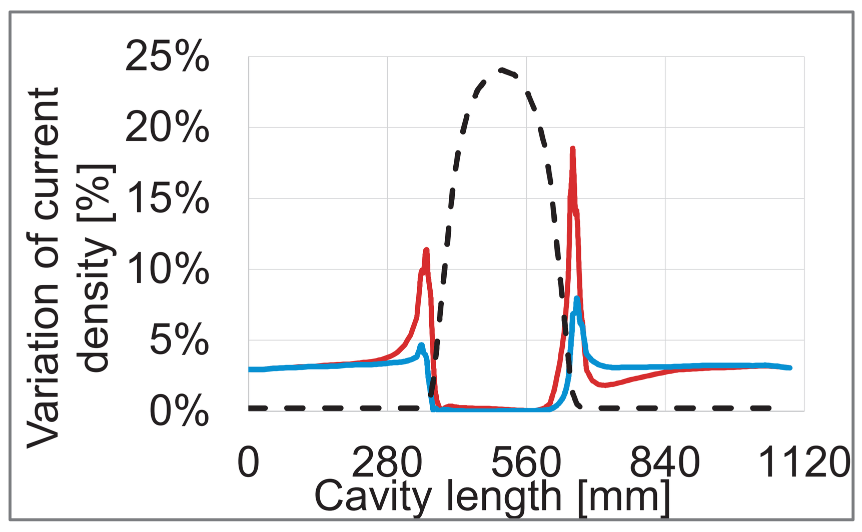


Figure 6. Cathode 'a', cathode 'c', - cavity shape.

Conclusions

The work developed with COMSOL Multiphysics® using the SCD physics interface, allowed to define the cathode geometry that ensures an as even as possible current density across the RF structure with minimum power input. Consequently the DC power supply voltage, the current needed as well as chiller cooling power were selected. The CFD Module was used to optimize and assess the impact of the flow dynamics on the EP reaction rate evenness. A cathode shape which presents a more homogeneous electrolyte velocity distribution across the cavity surface was identified. Besides, the definition of a correlation between the current density and the shear rate allowed to quantify the impact of the fluid dynamics in the EP etching rate, observing an increase up to 18% in the iris of the cavity and around 3%in the cut-offs, due to the higher shear rates.

References

1. T.D. Ecclestone, 'Defining the optimum tools and working conditions for copper electrochemical polishing', CERN, Geneva, Switzerland, https://edms.cern.ch/document/1844296/1.
2. V. Palmieri, 'Fundamentals of electrochemistry- the electrolytic polishing of metals: Application to copper and Niobium', Proceedings of the 11th Workshop on RF-Superconductivity, September 2013, DESY, Germany.